JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

NOVEMBER

1942

Volume 1 Number 4

CONTENTS

	Page
The design of animal husbandry experiments. E. W. Crampton	263
The effect of adding large amounts of cottonseed meal to a lamb fattening ration. H. M. Briggs and V. G. Heller	277
Length of feeding period and number of animals required to measure economy of gain in progeny tests of beef bulls. Bradford Knapp, Jr., Ralph W. Phillips, W. H. Black and R. T. Clark	285
Non-randomness of variations in daily weights of cattle. G. A. Baker and H. R. Guilbert	293
The effect of number of daily milkings upon persistency of milk production. I. Ludwin	300
A study of estrus and ovulation in the mare. John N. Cummings	309
Dilutors for stallion and jack semen. V. R. Berliner	314
Vitamin B_6 (Pyridoxine) in the nutrition of the pig. E. H. Hughes and R. L. Squibb	320
Experimental design for testing inbred lines of swine. G. E. Dickerson	326
Abstracts of papers to be presented at annual meeting of American Society of Animal Production.	
Animal breeding section	341
Artificial insemination section	344
Beef cattle section	344
Dairy cattle section	347
Extension section	349
Horse and mule section	350
Meats section	351
Nutrition section	352
Pasture and range section	354
Sheep and wool section	355
Swine section	358
News and Notes	361
Subject Index for Volume I	363
Author Index for Volume I	367

THE DESIGN OF ANIMAL HUSBANDRY EXPERIMENTS[1]

E. W. CRAMPTON[2]
Macdonald College

THE PAST quarter of a century has seen many changes and refinements in the technique of Animal Husbandry experimentation. Most of these changes have accompanied or followed the gradual increase in the use of statistical methods in the interpretation of the data. This was indeed a logical development, for if the problems are statistical in nature, their solution should be facilitated by employing statistical methods. In the early stages of this development the majority of refinements introduced were aimed at reducing the variability between individuals within experimental groups. Not all of the procedures advocated were effective, but the experimenter was evidently becoming increasingly aware that because animals on the same treatment behaved differently, there was an uncertainty about the cause and significance of differences in behavior between animals in contrasted experimental lots.

Some of the schemes used in attempting to reduce to a minimum the within lot variations actually defeated the objective by invalidating the data for statistical examination and subsequent interpretation. For example, the selection of animals for a feeding trial on the basis of rate of gain during a preliminary period, discarding those gaining below or above arbitrarily set limits, leaves a group no longer a random sample of any definable population which they are expected to represent in the interpretation of the test. Incidentally, it may be noted that according to data at Macdonald College this procedure can not be expected either to eliminate poor gainers or to guarantee less variable gains during the experiment. Actually a correlation of only +.0917 was found between the average daily gain of pigs from weaning time to 70 pounds weight and their subsequent gains to 200 pounds; while the coefficient of variation of the gains in the preliminary period was 12.4% as compared to 10.4% in the following period.

There are procedures, however, which are highly effective in reducing to a practical minimum the variability of the items on which the interpretation of the experiment is to be based. Before proceeding to a consideration of some of these procedures, it will be well to visualize clearly the reasons for the employment of statistical methods and the demands which these methods impose on trial design.

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Quebec, Canada. Journal Series No. 167.

[2] Professor of Animal Nutrition.

The Role of Statistical Methods in Animal Husbandry Experiments

There are at least two reasons for using statistics in Animal Husbandry experiments. The first is one of convenience and accuracy of description. One of the most valuable characteristics of modern statistics is that it succeeds in giving a clear picture of a group without a complete enumeration of all the items in the group. It is true that in such descriptions, the individual case or rather the irregularities in individual cases are hidden from direct view. But to the extent that such individual items becloud rather than clarify the group picture, the suppression of these irregularities is desirable. Obviously if the individual items are important, other or supplementary means of description must be employed. In the majority of Animal Husbandry experiments it is the group requiring description rather than the single item.

The extent of the description needed will depend on the project. It should not be more elaborate than necessary to a clear understanding of the particular case. Averages, if accompanied by standard deviations, yield a surprisingly concise and still comprehensive picture. These together with regressions and/or correlation coefficients to indicate possible relationships of the group to other groups, complete the statistical description of the data for the typical experiment.

Secondly, as a means of testing the significance of the effects of some imposed experimental condition or the testing of some hypothesis, statistical methods find their most often advocated use. Incidentally, it may be noted that adequate statistical description of the groups frequently suffices to indicate any significance of the treatment. In more complicated cases, so many factors are involved that no clear picture of the results is possible without the help of an analysis of the figures. Statistical tests of significance, however, place certain restrictions on the data to be analyzed. And herein lies one important reason for careful trial design.

Fundamentals of Experimental Design

An Animal Husbandry experiment should be so designed that: (1) the imposed conditions to be measured statistically shall operate without bias; (2) other factors known or suspected to be of importance to the results are subject to control or measurement either in allotment or by statistical procedures; (3) a valid estimate of the inherent and unaccounted for variations between the animals can be obtained.

The requirement that data be free of systematic errors and that the imposed and other conditions under consideration be free to operate without bias implies that animals be allotted to treatments by some system of randomization. The practice of "equalizing" lots as to initial weight, for ex-

ample, is contra-indicated. Theoretically, random allotment should result in equalized lots. In practice, because of limited numbers of animals, there will be small and usually statistically unimportant deviations between the lot averages.

The importance of "equal" initial weights of animals at the start of a feeding test will depend in considerable measure on whether or not initial weight is correlated with the criterion used as a basis of the interpretation of the trial. For example, there is a relatively wide range of initial weights within which the differences are not correlated with gains subsequently made by the animals during the test. Equalizing initial weights more closely than the limits of this range adds no precision to the experiment.

In a series of experiments at Macdonald College, the standard deviations of the initial weights of pigs ranged in different trials from two to seven pounds. The extent to which this degree of variation influenced the gains in weight during the subsequent feeding periods is measured by the partial regression coefficients of gains on initial weight, with feed intake held constant.

It was found from these data that the daily gain between the start of a pig feeding trial and a weight of 100 lbs. may be expected to be changed by some 0.0047 lb. per day for each pound difference in initial weight; and 0.003 lb. per day during a feeding period to 200 lbs. live weight. Given a feeding period of 100 days, each pound difference in initial weight then means 0.3 lb. in the total gain. Ten pounds discrepancy from equal initial weight of groups or individuals would then result (in these trials) in but three pounds of gain—(a matter of 1.8 per cent error on a gain of 165 lbs.) if initial weight were disregarded entirely.

On the other hand there are trials in which it may be impossible or undesirable to arrange for approximately equal initial weights. Indeed the effect of this factor may be one under consideration. With proper design of trial, the effects of varying initial weight may be accurately measured and subsequently such items as gain be adjusted quantitatively for these effects. For many comparative feeding trials it may be desirable as a matter of routine to adjust the gains by regression to average initial weight and average feed intake.

A valid estimate of error requires a measurement of the variation between the individuals which is independent of that traceable to any of the conditions intentionally taken into account in the experiment. There is no difficulty with the theory involved. Provision for this measurement, however, is the primary reason for a particular trial design. Experiments set up to permit statistical analysis are primarily those so planned that the total variability, as measured by the squared standard deviation (or variance), may

be divided into the fractions traceable to one or more specific causes. All of the variability which is not thus accounted for is the result of the unmeasured factors affecting the behavior of the animals in regard to the characteristic under consideration.

The total variance and all fractions of it are expressed as averages. By definition the variance is the average squared deviation of single observations from their mean. Thus the number of variates making up the group on which the measure of variations is made must be known. It is not the total number in the group or sub-group, however, which is used to obtain the variance, but the number of individuals in the group which are free to vary entirely at random. This number is called in statistical terms the "degrees of freedom."

It is not the intention of this paper to discuss the terms or formulae used in statistical procedures. The matter of degrees of freedom, however, has a direct bearing on trial design in that the precision obtainable in such trials is in part determined by the number of degrees of freedom which will be available for the estimate of error. Since each sub-group and each statistical constant calculated from the data reduces the residual degrees of freedom, the number of independent observations (i.e. the degrees of freedom) available for the estimate of error is always less than the total numbers in the test. In general, precision begins to be lost when the number of degrees of freedom available for "error" is less than twenty. This fact is always in mind when designing a trial and often is the reason for certain of its features.

Factorial Design for Comparative Feeding Experiments

For the "run of mine" feeding tests there is probably no more efficient and generally useful scheme of allotment than that known as the Factorial Design proposed by Fisher and referred to as a "Method of Indirect Replication" in a report to the American Society of Animal Production in 1932 by the Committee on Methods of Investigation. This allotment design will be described in general pattern which will serve to illustrate its features and indicate its field of applicability.

For an example a comparative feeding trial recently completed at Macdonald College (Crampton, 1941) will be used. This was a study of protein-vitamin supplements to a basal ration of barley. The detail of ration composition is of no concern at this time. Enough to state that we wished to investigate the effect on gains in live weight and on carcass excellence of possible changes in our standard mixed protein supplement; and were also concerned about the proportion of the supplement to basal feed desirable in the ration.

In the design of an experiment to study these questions, it was desired to

control as far as possible other factors known to affect or suspected of affecting the results. Thus seasonal differences in the growth of pigs, as between winter and summer born litters, needed to be taken into consideration, and also those due to sex. The problem of feed intake is not a matter of allotment design and will be considered later.

It is at once obvious that this test must involve two feeding periods—one

TABLE 1.—SINGLE FACTORIAL DESIGN OF ALLOTMENT OF PIGS TO A TEST OF HIGH VS. LOW PROTEIN LEVEL. (ANIMALS TO BE RANDOMIZED TO THE LOTS)

Low Protein	High Protein
1	25
2	26
3	27
4	28
5	29
6	30
7	31
8	32
9	33
10	34
11	35
12	36
13	37
14	38
15	39
16	40
17	41
18	42
19	43
20	44
21	45
22	46
23	47
24	48

TABLE 1A.—ANALYSIS OF VARIANCE

Source of variance	*D/F*
All causes	47
Between two lots	1
Within lots (error)	46

for winter born pigs and a second for summer litters. These two units must of course be replicates in all other respects. Within each season's test a comparison of level of protein might be arranged in the conventional way as in table 1. Using 48 pigs, an analysis of the variance might be made as in table 1a, there being 46 degrees of freedom on which to base an estimate of the "error" variation (in gain or in any other item measured) irrespective of the difference in protein level of their diets. This would be a single factor design.

The results of such a test, using 24 animals per lot should be reasonably

conclusive. However, these same pigs may be used to yield data on other questions with very little sacrifice in the reliability of the answers. For example, we may test the effect of the omission of fish meal from the protein supplement at both levels of intake. This plan may be illustrated as in table 2.

By this arrangement there are still 44 degrees of freedom (see table 2a) available for estimating the significance of differences resulting from comparison of 24 pairs of animals between any two of which protein level is the only ration difference, plus 24 pairs of animals between any two of which the presence or absence of fish meal in the protein supplement is the only ration change.

TABLE 2.—ALLOTMENT PLAN—FACTORIAL DESIGN TO TEST HIGH VS. LOW PROTEIN WITH AND WITHOUT FISHMEAL

Low protein		High protein	
Without fishmeal	With fishmeal	Without fishmeal	With fishmeal
1	13	25	37
2	14	26	38
3	15	27	39
4	16	28	40
5	17	29	41
6	18	30	42
7	19	31	43
8	20	32	44
9	21	33	45
10	22	34	46
11	23	35	47
12	24	36	48

TABLE 2A.—ANALYSIS OF VARIANCE

Source of variance		*D/F*
All causes		47
Between 4 sub groups		3
Made up of:		
High vs. low protein	1	
Fish vs. no fish	1	
Interaction protein vs. fish	1	
Within sub groups (error)		44

It is still not unreasonable to ask these 48 pigs to answer another question or two while they are being examined, and in this case we were interested in whether or not the addition of some source of the vitamin B complex would improve the ration. This could be examined in this experiment at two protein levels and in rations with and without fish meal. Skimmilk powder and dried brewers yeast were both possible sources of the B vitamins wanted. To include them, the plan of allotment might be changed to that shown in table 3.

The answer as to whether or not male pigs would respond differently than females to these several rations, requires only one other provision in the allotment plan. When combined with the second season's feeding the completed design involves 96 pigs, as shown in table 4.

TABLE 3.—ALLOTMENT PLAN—FACTORIAL DESIGN TO TEST THE VALUE OF MILK OR YEAST IN RATIONS WITH AND WITHOUT FISHMEAL AND AT HIGH AND LOW PROTEIN LEVELS

Protein / Vitamin B	Low protein		High protein	
	Without fishmeal	With fishmeal	Without fishmeal	With fishmeal
Without yeast or milk	1	13	25	37
	2	14	26	38
	3	15	27	39
	4	16	28	40
With milk powder	5	17	29	41
	6	18	30	42
	7	19	31	43
	8	20	32	44
With dried yeast	9	21	33	45
	10	22	34	46
	11	23	35	47
	12	24	36	48

Table 4 is a facsimile of a data form used for recording the data from this test. The figures on this particular sheet are the pig numbers as actually allotted. The sexes were of necessity randomized independently. Forms ruled as in table 4 were used for each item of data recorded during the experiment. Table 4a shows how the variance in a trial of this design may be partitioned.

At this point, it may be well to summarize the features of this particular example of Factorial Design.

It violates the often stressed doctrine of varying essential conditions only one at a time. Recent developments in experimental procedure, however, cast some doubt as to the necessity or advisability of this plan in a variety of animal husbandry experiments. On theoretical grounds it may be argued

TABLE 3A.—ANALYSIS OF VARIANCE

Source of variance	D/F	
All causes		47
Between 12 sub groups		11
Made up of:		
High vs. low protein	1	
Fish vs. no fish	1	
Milk vs. yeast vs. neither	2	
Interaction (total)	7	
Within sub groups (error)		36

TABLE 4.—SAMPLE DATA SHEET SHOWING PLAN OF ALLOTMENT OF 96 PIGS TO FEEDING TRIAL

Season	Protein level / Vitamin B supplement	Fish vs. no fish / Sex	High protein: Without fishmeal	High protein: With fishmeal	Low protein: Without fishmeal	Low protein: With fishmeal
January born pigs	Without yeast or milk	♀	590 596	527 568	580 564	592 586
		♂	560 542	536 572	591 540	589 553
	Milk	♀	597 548	528 598	539 531	547 599
		♂	534 538	573 585	550 519	556 529
	Yeast	♀	577 567	595 517	525 549	551 594
		♂	552 571	587 535	533 566	574 570
May born pigs	Without yeast or milk	♀	669 640	602 612	606 633	694 660
		♂	620 654	603 623	689 629	695 626
	Milk	♀	644 625	619 642	632 609	656 643
		♂	657 637	606 693	628 601	616 668
	Yeast	♀	655 630	692 600	607 634	635 671
		♂	614 615	679 604	605 631	622 651

that in practice, one does not find factors operating one at a time, and hence the interactions between two or more factors may be of as much significance in the observed results as the primary factors singly. Rigid control of all conditions but a single one under special study may therefore give results

from which generalizations cannot be made. Exact standardization of experimental conditions always carries with it the disadvantage that an experiment conducted under such conditions yields direct information only within the narrow range of such conditions.

The factorial arrangement on the other hand has the advantage of greater comprehensiveness, permitting with equal precision, in this example, not only comparison between six primary treatments but an evaluation also of the 41 interactions which may be involved.

TABLE 4A.—ANALYSIS OF VARIANCE

Source of variance		Degress of freedom	
All causes			95
Between 48 sub groups of two pigs each			47
Made up of:			
Between two levels of protein	(48 pigs per group)	1	
Between fish vs. no fish	(48 pigs per group)	1	
Between two sexes	(48 pigs per group)	1	
Between two seasons	(48 pigs per group)	1	
Between milk vs. yeast vs. neither	(32 pigs per group)	2	
*Interactions including,		41	
1st order interactions		14	
Higher order interactions		27	
Within sub groups			48
Error (if higher order interactions are insignificant)			75

* These may be evaluated separately if desired.

It is obviously more efficient than single factor tests if by efficiency is meant more information obtainable from a given number of animals with no appreciable sacrifice in precision. A total of 96 pigs in this test permits direct comparisons which would require 480 pigs if single factor design were employed. Add to this the information which measurement of the interactions may yield and there can be no question of the relative efficiency of the Factorial Design over the older procedures.

The precision of the test is satisfactory. Ninety-six pigs used in a conventional single factor arrangement, i.e. two lots of 48 pigs each, would furnish 94 degrees of freedom for error. In this trial 96 pigs yield a minimum of 48 degrees of freedom for error. The t values (at odds of 19:1) for $n=94$ and 48 are 1.986 and 2.010 respectively. The maximum loss in precision therefore from a single factor design amounts to about 1 per cent.

TABLE 5.—ALLOTMENT PLAN FOR STUDY OF DIGESTIBILITY OF BASAL FEEDS (FIGURES ARE PIG NUMBERS)

Series and year	Basal feeds to be tested	Age groups			
		3 months	4 months	5 months	6 months
A 1942	Barley	1	2	3	4
	Screenings	2	3	4	1
	Oats	3	4	1	2
	Feed oats	4	1	2	3
B 1943	Corn	5	6	7	8
	Wheat	6	7	8	5
	Middlings	7	8	5	6
	Shorts	8	5	6	7
C 1944	Bran	9	10	11	12
	Alfalfa meal	10	11	12	9
	Rice feed	11	12	9	10
	Homing feed	12	9	10	11
D 1945	Buckwheat	13	14	15	16
	To be selected	14	15	16	13
	To be selected	15	16	13	14
	To be selected	16	13	14	15

Experiments Involving Few Animals

Animal Husbandry experiments include types of trials other than the familiar comparative feeding test. Frequently these trials are of such a nature that it is difficult to utilize large numbers of animals, with the result that the degrees of freedom for estimating experimental error are few and the trial suffers in precision. Advantage may be taken in these cases of a design which will permit the efficient use of the animals and yield at the same time a valid estimate of error.

Digestion trials might be cited as falling into the class of trial involving very small numbers of animals. Table 5 illustrates a design applicable to such projects. Only four animals are involved in any one year and in the complete study there are but 16 different animals used. The scheme of statistical analysis possible is shown in Table 5a. It will be noted that information is yielded not only on the digestibility of feedstuffs but also on differences in digestibility with age.

Statistical Control of Correlated Variables

A discussion of the question of design of Animal Husbandry experiments is incomplete without consideration of a method of increasing their preci-

TABLE 5A.—ANALYSIS OF VARIANCE

Source of variance	*D/F*
All causes	63
Between 4 series	3
Between 4 pigs in 4 series	12
Between 4 ages	3
Between 4 feeds at 4 ages	12 (error for feed differences)
Interactions of period × series	9
Residual—within series	24 (error for ages differences)

sion through the elimination of causes of variation which cannot or are not controlled in the allotment plan. In many trials feed is allowed ad libitum. In but few it is successfully controlled to equal intake by different animals. Variability of the gains made during the trial is then in part traceable to variability in the feed consumption. In trials in which a record of the feed intake can be and is made, that part of the variance in gains due to unequal consumption may be estimated and the variance for gains be adjusted accordingly. The procedures involved are those of regression and are quite straightforward. If but a single such item, as feed intake, is involved, the simple regression coefficient measures the amount of the variance due to that item.

If more than one such factor is taken into consideration, such as both feed consumption and initial weight, partial regression is employed. The individual partial regression coefficients measure the average effects on the dependent variable, such as gain, of unit changes in the respective independent variables. The squared multiple correlation coefficient calculated from these independent variables measures the fraction of the variance traceable to the combined effects of the independent variables.

Statistical corrections (by regression) of the variance to remove the portions traceable to the independent variables concerned requires also an adjustment of the degrees of freedom. In general one degree of freedom is "used up" for each such independent variable and thus the degrees of freedom available for the estimate of error are reduced correspondingly. The increase in precision by correcting for feed intake in feeding tests in which live weight gain is the criterion may be very considerable. On the other hand the gain in precision by correcting for variation in initial weight where the range of this variable is not large may be entirely insignificant. Table 6 gives typical data relative to the effectiveness of statistical correction of gains for the effects of varying initial weight and feed intake of pigs.

It is obvious from the above discussion that in order to make the most efficient use of the animals of an experiment they must be treated as individuals

TABLE 6.—INCREASE IN PRECISION IN HOG FEEDING TRIALS RESULTING FROM ADJUSTMENT OF RESIDUAL VARIANCE FOR GAINS BY REMOVAL OF VARIANCE TRACEABLE TO INITIAL WEIGHT AND/OR TO FEED INTAKE

(Data from feeding trials at Macdonald College)

Exp. No.	Partition of variance	D/F	$S(x-\bar{x})^2$	Variance	Standard deviation	Relative precision
73 (42 day gains)	All causes	79	22881			
	Between groups	8	16342			
	Within groups (error)	71	6538	92	9.6	340
	Regression for feed and initial weight	2	4653			
	Remainder (error)	69	1885	27	5.2	100
98 Daily gain to 70 lbs.	All causes	95	1.6279			
	Between groups	47	.9455			
	Within groups (error)	48	.6823	.0142	.12	164
	Regression for initial Wt.	1	.0020			
	Regression for feed intake	1	.2848			
	Remainder (error)	46	.3955	.0086	.09	100
107 Daily gain to 100 lbs.	All causes	59	1.3704			
	Between groups	11	.5148			
	Within groups (error)	48	.8556	.0178	.13	118
	Regression for feed intake	1	.2533			
	Remainder (error)	47	.6023	.0128	.11	100

in respect to each item which is to be studied or analyzed statistically. Thus for comparative feeding tests individual feeding is practically an essential part of the design. Without individual feed intake records the precision of the tests will in most cases be materially decreased.

In this connection, it might be noted that arbitrary corrections for correlated variables is often made. The calculation of gain, for example, is a method of correcting final weights for varying initial weights. An adjustment frequently made in an attempt to allow for varying feed intake is the calculation of the gain/feed ratio. There is no particular objection to this ratio as a basis of comparing average ration efficiency. It is not permissible, however, to calculate for each animal such a number and then to apply an analysis of variance to this array of figures.

This is because in the original calculation of the gain/feed ratio is introduced an error occasioned by the fact that not all the feed eaten by an animal produces a gain in live weight. The analysis of variance therefore will include a systematic error which may be of sufficient size to distort the result and to vitiate the estimate of experimental error.

There are trials in which it is desirable to eliminate entirely a factor which

is known to be related to the item being studied, as illustrated by tests in which so-called "paired feeding" is employed. This is individual feeding subject to a further restriction that the pair mates shall be fed equal quantities of their respective diets. The particular requirements of the experiment will dictate the use of such specific methods of control of variation. Care must be taken that these methods do not bias or otherwise invalidate for statistical study the condition being studied. For example, selection of experimental animals for equal initial weights may be definitely contraindicated in tests the results of which are to be applied to pigs of certain age groups, since within age groups there is normally considerable variation in weight. The experimental group thus selected no longer is a random sample of the true population it is presumed to represent.

The procedures of adjustment of the variance of a dependent variable for the effects of related independent variables has a wide field of applications in Animal Husbandry experiments quite aside from the example of the comparative feeding trial. For instance, following publications of McMeekan's (1938) results, showing that rate of gain of pigs was a factor in type of bacon carcass produced, it was desired to find out whether the range of variations in rate of gain encountered in the ordinary farm feeding of market hogs would have any significant effect on carcass leanness. A feeding trial was conducted (Crampton, 1940) in which among other items, daily gain, percentage lean area in the bacon rasher, and length of carcass side were recorded and analyzed by means of partial regression. The latter measurement was included because of its known association with leanness of the carcass. From the data a squared multiple correlation coefficient of $R^2 = 0.0094$ was found, indicating that the total variance of the per cent lean in the bacon rasher could be reduced only by 0.94 per cent if variation in rate of gain and length of side could be entirely eliminated. In other words these two variables appeared to account for less than 1 per cent of the variability in the leanness of the bacon carcass. Furthermore the partial correlation between leanness and rate of gain where length of side was statistically held constant, was found to be $r = 0.022$, an obviously insignificant figure. Table 7 shows the essential part of the analysis of variance for per cent lean in the bacon rasher. The insignificant effect of two independent variables in question is shown by the small change in the variance of the per cent lean after that due to these variables was deducted.

The number of independent variables which may be studied by this method is limited only by practical considerations of time and the facilities required for the calculations which become increasingly laborious as the number of variables multiplies.

It cannot be too often pointed out that experimentation is not and cannot

be standardized beyond the few fundamental principles of procedure. Each problem demands individual consideration, and the ingenuity of the experimenter in the design of tests plays no small role in its solution. Statistics should be regarded as a tool, or better as a set of related tools; extremely useful in the hands of the worker who understands their use and limitations. The ability to design experiments to permit the use of statistics and the selection of the specific statistical methods most useful in the case at hand should be as much the stock in trade of the Animal Husbandry research

TABLE 7.—PARTIAL ANALYSIS OF VARIANCE OF PER CENT LEAN IN BACON RASHERS

Source of variance	D/F	$S(x-\bar{x})^2$	Variance	Relative precision
Within groups (error)	171	3524	20.6	995
Regression of daily gain and carcass length	2	33		
Remainder (error)	169	3491	20.7	1000

worker as is the ability of the wood turner to set up and adjust a lathe to permit the efficient use of his chisels. In the selection of the specific tool in a particular case, both craftsmen have some choice. There can be no doubt, however, that skill in the use of tools, be they biological, mathematical, or mechanical devices, comes only through actual application. If this paper has given, for a few types of experiments, some idea of designs which will insure that the data eventually collected may be efficiently worked with statistical tools, it has served its purpose.

Literature Cited

Crampton, E. W. 1940. Hog Carcass Studies. Effect of Early Rate of Growth on Leanness of Carcass. Sci. Agr., 20, 592.

Crampton, E. W. 1941. Protein-mineral-vitamin Supplements to Barley in Market Hog Rations. Sci. Agr., 21, 613.

McMeekan, C. P. 1938. Shape of the Growth Curve as a Controlling Factor in Confirmation and Anatomical Composition of the Animal Body—Swine. Amer. Soc. Animal Prod. Proc., p. 337.

THE EFFECT OF ADDING LARGE AMOUNTS OF COTTONSEED MEAL TO A LAMB FATTENING RATION

H. M. Briggs and V. G. Heller[1]
Oklahoma Agricultural Experiment Station[2]

Introduction

IN CERTAIN areas in the southern part of the United States, cottonseed meal is at times less expensive than corn for feeding livestock. A series of feeding experiments has been conducted by Briggs (1941) with fattening lambs in which it has been determined that cottonseed meal was worth approximately 81% the value of shelled yellow corn when fed in larger amounts than needed to supply the optimum protein requirements.

Kuhlman, *et al.* (1936) have successfully fed dairy calves from weaning through a lifetime of production with cottonseed meal as the sole concentrate. Kuhlman and Gallup (1940) have found that the replacing of one-half the corn and oats in a check ration with a like amount of cottonseed meal did not reduce the milk flow. Blizzard and Taylor (1940) have likewise demonstrated that cottonseed meal is equivalent to No. 2 shelled corn, after the protein requirement has been satisfied, in replacing one-half the corn in the ration of fattening steer calves.

In light of the very favorable results with cottonseed meal as a fattening or milk-producing feed for cattle, a series of digestion and retention studies was outlined to determine in what way the high protein feed did not compare favorably with corn for fattening lambs. The ratio was studied as a unit, as Forbes, *et al.* (1933) have pointed out that the feeding value of a feed may vary widely depending upon the combination in which it is used.

Procedure

Three digestion trials were conducted in which 16 wether lambs were used. Eight lambs were used in the first trial and eight additional lambs were used in the other two trials. Twenty-four separate determinations were therefore made on each ration. The lambs were grade Rambouillet feeder lambs and represented the larger lambs secured in carlots of feeders from the Texas range. Their average weight at the time of their selection was approximately 80 pounds and all lambs gained weight during the experimental feeding. The lambs were treated with the standard copper-sulphate

[1] The authors are associate animal husbandman and head, Department of Agricultural Chemistry Research, respectively.
[2] Stillwater, Oklahoma.

nicotine-sulphate drench for internal parasites before experimental feeding was started.

The lambs were each fed test rations for a 10-day preliminary period in a 3′×5′ pen and then placed in false bottom cages for a 10-day collection period. The cages were similar to those described by Forbes (1915). Small gains were registered by the lambs in the preliminary pens but greater increases in weight resulted when the lambs were confined to the cages. This was perhaps the result of less activity.

The procedure used was very similar to that reported by Briggs and Heller (1940). Each lamb was fed the daily rations given in table 1. The feeds for each feeding were weighed on a scale sensitive to 0.1 gm. and stored in paper bags prior to the experiment. Each lamb was fed in an open bucket while in the preliminary pen, but in a specially constructed feeder while in the cage. The lambs were fed at approximately the same time each morning and evening and received one-half the daily ration at each feeding. Fresh, clean water was placed before the lambs twice daily and allowed to remain until the following feeding. Approximately 8 grams of salt was added to the feed each morning and evening.

Fecal collections were made each morning at the same hour. Each collection was dried separately until the next collection over an electric heater and was weighed and sealed. After the 10-day collection period, the dry feces were placed in a basket, thoroughly mixed, and representative samples were taken for chemical analysis. Urine collections were made in a glass container, acidified with sulphuric acid, and stored for the duration of the collection period. The volume was then determined and an aliquot taken for analysis.

TABLE 1.—QUANTITATIVE COMPOSITION FOR THE DAILY RATIONS USED IN DIGESTION TRIALS WITH LAMBS

Component	Ration			
	A		B	
	grams	*percent*	*grams*	*percent*
Corn (yellow)	408	44.9	227	25.0
Cottonseed meal	46	5.1	227	25.0
Alfalfa hay	454	50.0	454	50.0

The chemical composition of feeds used during the trials are given in table 2. Trial 1 was conducted from December 11, 1939, to March 6, 1940. The second and third trials were completed respectively from December 21, 1940, to January 22, 1941; and from February 1, 1941, to March 3, 1941. The same feeds and the same lambs were used in both trials. The feeds used

were grown in the year prior to their use and were apparently normal feeds in every respect.

TABLE 2.—PERCENTAGE COMPOSITION OF FEEDS USED IN THREE DIGESTION TRIALS WITH LAMBS

Feed	Water	Protein	Fat	Crude fiber	Ash	Nitrogen free extract	Ca	P	Mg
Trial 1.—December 11, 1939, to March 6, 1940									
Corn	10.38	10.53	3.73	1.91	1.20	72.25	0.02	0.25	0.11
Cottonseed meal	8.47	41.50	5.75	14.67	6.46	23.15	0.18	1.12	0.63
Alfalfa hay	9.83	19.35	2.68	23.40	8.31	36.43	1.27	0.25	0.32
Trials 2 and 3—December 21, 1940, to March 3, 1941									
Corn	13.95	10.00	4.15	2.45	1.64	67.81	0.03	0.36	0.14
Cottonseed meal	7.84	42.56	6.94	8.62	5.48	28.56	0.16	0.94	0.55
Alfalfa hay	10.65	19.01	2.79	20.60	9.85	37.10	1.55	0.22	0.32

Results

The apparent digestion coefficients secured in these experiments are presented in table 3. Each lamb used in the study received both rations once, and one-half of the lambs received each ration twice. The calcium, phosphorous, magnesium and nitrogen retentions of each lamb were obtained for each ration and are given in table 4.

Discussion

The lambs ate their full allowance of the two rations readily and with apparent equal relish.

The data presented in tables 3 and 4 showed little variation between periods and consequently were studied together and analyzed by the method of Snedecor (1937).

The Effect of Large Amounts of Cottonseed Meal on the Digestion of the Ration

During the three trials the two rations used were identical except that 181 grams of cottonseed meal was used in the high cottonseed meal ration to replace a like amount of corn in the low cottonseed ration. The two rations were very similar to those that have been used by Briggs (1941) in fattening lambs in dry lot.

TABLE 3.—THE EFFECT OF DIFFERENT LEVELS OF COTTONSEED MEAL ON THE APPARENT DIGESTIBILITY (PER CENT) OF LAMB RATIONS

Lamb No.	Protein digestion coeff. for ration		Fat digestion coeff. for ration		Crude fiber digestion coeff. for ration		Nitrogen-free extract digestion coeff. for ration	
	Low c.s.m.*	High c.s.m.*	Low c.s.m.	High c.s.m.	Low c.s.m.	High c.s.m.	Low c.s.m.	High c.s.m.
103	71.3	76.6	81.7	84.3	45.9	51.2	85.8	81.5
124	75.0	78.0	74.8	83.2	46.0	46.3	85.9	80.7
130	76.5	74.7	76.6	80.7	53.8	52.0	85.9	82.5
171	77.3	81.9	66.2	80.3	50.9	49.6	87.7	80.9
146	71.7	80.1	78.9	79.6	43.5	49.2	86.3	81.4
119	74.9	78.0	74.1	83.1	47.7	43.5	86.4	81.0
133	75.0	75.7	74.3	80.1	47.9	44.2	86.4	80.0
491	77.4	78.1	67.3	71.4	46.5	40.5	86.6	82.3
Average	74.9	77.9	74.2	80.3	47.8	47.1	86.4	81.3
95	78.2	80.2	71.2	68.2	51.2	44.2	88.0	83.3
64	71.7	75.7	63.5	70.7	47.6	42.4	87.1	82.2
437	75.3	77.1	77.1	75.6	47.2	47.5	87.2	82.3
12	74.3	77.2	74.6	76.9	47.8	49.9	87.4	83.1
406	75.3	73.8	73.7	72.0	46.9	46.0	85.9	85.5
410	62.6	75.6	73.7	72.4	49.0	48.1	87.8	82.1
409	72.6	73.9	73.2	76.7	49.6	37.9	86.1	79.5
15	72.7	75.2	72.2	81.3	48.5	43.3	87.1	81.0
Average	72.8	76.1	72.4	74.4	48.5	44.9	87.1	82.4
95	78.2	78.9	72.3	78.8	48.6	45.4	86.4	83.3
64	71.4	75.7	69.0	79.0	45.6	41.9	85.4	82.4
437	70.7	79.0	80.1	79.5	33.5	43.7	89.6	83.8
12	74.3	77.6	71.6	75.4	37.3	40.8	89.1	84.9
406	75.7	78.5	77.2	79.2	46.8	49.4	88.0	80.7
410	73.4	79.2	71.1	78.8	43.2	48.4	84.8	81.2
409	70.7	75.9	73.7	80.9	38.1	36.3	88.0	83.3
15	71.7	77.9	72.0	73.6	42.6	28.6	85.9	83.5
Average	73.3	77.8	73.4	78.1	42.0	41.8	87.1	82.9
Average coefficient (3 trials)	73.7	77.3	73.3	77.6	46.1	44.6	86.9	82.3

* Low and high allowances of cottonseed meal respectively.

The ration containing the larger amount of protein had an average apparent digestion coefficient of 77.3 per cent as compared to 73.7 per cent for the low cottonseed meal ration. This difference of 3.6 per cent, while not large, was highly significant, as all differences were in the same direction except coefficient of lamb No. 406 in the second trial. This is in agreement

TABLE 4.—THE MINERAL AND NITROGEN BALANCE (GRAMS) OF LAMBS FED HIGH AND LOW LEVELS OF COTTONSEED MEAL FOR A TEN-DAY PERIOD

Lamb No.	Calcium retention		Phosphorus retention		Magnesium retention		Nitrogen retention	
	(A) Low c.s.m.*	(B) High c.s.m.*	(A) Low c.s.m.	(B) High c.s.m.	(A) Low c.s.m.	(B) High c.s.m.	(A) Low c.s.m.	(B) High c.s.m.
103	4.8	17.1	.7	4.1	2.1	2.8	52.3	18.2
124	11.1	4.9	4.7	4.1	3.2	.8	60.4	47.3
130	15.2	10.3	9.1	11.7	2.7	4.5	67.8	61.6
171	15.9	10.1	9.1	12.4	2.6	3.8	67.7	69.2
146	11.3	18.0	4.3	12.3	3.5	7.1	54.0	102.4
119	5.7	−2.6	5.0	8.5	.4	7.6	58.6	74.7
133	9.4	6.1	3.7	18.4	3.2	1.0	58.8	50.4
491	12.1	5.5	5.2	12.9	2.5	2.5	60.3	52.2
Average	10.7	8.7	5.2	10.5	2.5	3.8	58.7	59.5
95	19.1	8.1	3.3	10.3	−2.7	1.7	−64.9	52.0
64	17.2	4.6	1.6	8.9	−3.7	1.1	51.8	188.9
437	6.0	8.0	5.2	5.4	2.3	5.0	67.0	125.9
12	7.3	6.7	5.9	6.0	.6	3.7	48.2	52.3
406	7.1	−2.4	7.7	13.2	3.0	6.4	43.5	51.6
410	5.8	6.7	7.6	14.6	1.6	7.8	22.4	158.8
409	6.7	1.9	7.4	3.2	−4.7	−1.9	30.1	22.6
15	9.9	5.3	5.5	5.6	−.5	1.5	19.7	74.1
Average	9.9	4.9	5.5	8.4	−.5	3.2	19.7	90.8
95	.7	4.7	6.7	9.6	.4	−5.3	41.6	25.4
64	3.7	5.2	6.0	7.5	.0	10.5	43.2	51.8
437	10.2	12.6	1.3	9.2	−4.7	4.8	61.2	108.8
12	3.8	11.5	5.9	9.2	−3.6	6.6	33.6	140.7
406	11.8	10.2	8.7	10.5	11.4	1.9	−76.2	46.8
410	1.5	7.7	5.1	13.7	5.2	−.2	45.4	67.8
409	2.0	4.0	5.2	7.6	.1	−.9	51.9	47.4
15	4.7	−4.5	5.7	11.2	1.1	2.7	103.9	69.0
Average	4.8	6.4	5.6	9.8	1.2	2.5	38.1	69.7
Average retention (3 trials)	8.5	6.7	5.4	9.6	1.1	3.1	38.8	73.3

* Low and high levels of cottonseed meal respectively.

with Morrison (1936), who gives the digestion coefficient of protein in cottonseed meal as higher than that of corn. However, it should be kept in mind that the metabolic nitrogen of the high protein ration would no doubt make up a smaller proportion of the total nitrogen in the feces than would be true of the low protein ration. Hence an increase in the apparent digestion

coefficient of the higher level of protein might be expected even though the actual digestibility of the protein in the two feeds was identical.

The fat in cottonseed meal is also regarded by Morrison (1936) as more digestible than that in corn. In this study the ration with the large amount of cottonseed meal had an apparent digestion coefficient of 4.6 per cent greater than the low cottonseed meal ration. This difference was highly significant.

The average apparent digestion coefficient of the crude fiber, while lower for the high cottonseed meal ration, was not of significant difference. The apparent coefficient for nitrogen-free extract was higher in the ration containing the larger amount of corn; a highly significant difference of 4.3 per cent was observed. These differences likewise are in agreement with published coefficients of Morrison (1936). It would be expected that the N.F.E. of corn which contains considerable starch would be more digestible than the N.F.E. of cottonseed meal which contains very little starch.

Calculated T.D.N. values of the two rations, using the apparent coefficients of digestion secured in these trials, show ration A, or the low cottonseed meal ration, to have a T.D.N. value of 67.2 and ration B, or the high cottonseed meal ration to have a T.D.N. value of 65.7 or 97.8 per cent that of ration A. It becomes clear from these calculations that the T.D.N. of these rations are not a reliable guide to determined their value in light of the results secured in actual feed lot tests with fattening lambs by Briggs (1941).

The Effect of Large Amounts of Cottonseed Meal on the Retention of Nutrients

Including large amounts of cottonseed meal in a ration containing alfalfa hay as the sole roughage provided the lamb with considerable more phosphorus and magnesium as well as nitrogen than is found in normal rations. The calcium content of the two rations was very similar. A balance was conducted to study the reaction of the lambs to these conditions, particularly in regards to the storage of calcium and phosphorus with the inclusion of abnormally large amounts of phosphorus in the ration.

During the first trial ration A contained 5.93 grams of calcium daily and 2.67 grams of phosphorus or had a Ca-P ratio of 2.2:1. Ration B furnished 6.22 grams of calcium and 4.24 grams of phosphorus and had a Ca-P ratio of 1.5:1. In the second and third trials ration A carried a daily calcium allowance of 7.23 grams and ration B supplied 7.47 grams. The former ration supplied 2.90 grams of phosphorus as contrasted to 3.95 grams in the latter ration. Ration B therefore had a Ca-P ratio of 1.9:1 while the low cottonseed meal ration carried a Ca-P ratio of 2.5:1.

Irregular retention of both phosphorus and calcium was secured as shown in table 4. Three negative calcium retentions were obtained on the high cottonseed meal ration, while none were secured on the ration containing the smaller amount of phosphorus. The average difference in storage for the two rations in the three trials was 1.8 grams for each 10-day period but the difference was not significant. Two of the lambs that showed a negative balance of calcium when on the high phosphorus ration in one period had a positive balance the other period they were used. The calcium balance secured on the high phosphorus ration indicates that lambs can be fed phosphorus to the level of this trial with safety. This corresponds to results secured by Briggs (1941) in feeding lambs similar rations in dry lot.

An average difference of 4.2 grams phosphorus storage was obtained in the 10-day periods between the high and low cottonseed meal rations for the three trials. This difference in favor of the high phosphorus ration was highly significant. The high cottonseed meal ration more closely approaches the accepted Ca-P ration of 2:1 but under the conditions of this study the smaller allowance of phosphorus or wider ratio proved more advantageous from the standpoind of increased Ca storage.

The storage of magnesium was not consistent, but averaged 2.0 grams more for each 10-day period for ration B than for ration A. This difference was significant (5% point). The high-cottonseed-meal ration carried a daily allowance of 3.13 grams of magnesium as compared to 2.19 grams for ration A in the first trial. In the second and third trials the magnesium contents of the rations were 3.02 grams and 2.19 grams, respectively. Maynard (1937) has pointed out that with adequate intakes of calcium and magnesium the storage of either element is not interfered with by the other.

The storage of nitrogen was quite irregular. While the difference in average storage of 34.5 grams for the 10-day period is large, it is felt the data are too inconsistent to warrant any definite conclusions. The reason for such divergent values has not been determined, but it must be kept in mind that the low protein ration gave more satisfactory results when used to fatten lambs in dry lot. No correlation existed between the live weight gain during the 10-day collection period and the nitrogen storage of the period. The data were examined to determined if a residual effect of the previous ration was encountered, but no such tendency was observed. It does appear that both rations led to more than adequate nitrogen storage for fattening lambs.

Summary

In a series of digestion and retention studies, 181 grams of cottonseed meal were used to replace an equal amount of shelled yellow corn in a lamb fattening ration. Both rations contained 454 grams of alfalfa hay and the low

cottonseed ration contained 46 grams of cottonseed meal. The ration with the large amount of cottonseed meal had higher apparent digestion coefficients for protein and fat but lower for N.F.E. than the ration containing the small amount of protein supplement. These differences were highly significant. The apparent digestion coefficient of crude fiber was lower with an excess of the supplement.

Both rations resulted on the average in positive balances of calcium, phosphorus, magnesium, and nitrogen. The high cottonseed meal ration resulted in a highly significant increase in phosphorus storage and reduction in calcium storage. Average phosphorus retention was increased from 5.4 to 9.6 grams and calcium storage reduced from 8.5 to 6.7 grams in the 10-day periods. The higher magnesium storage was secured in the high cottonseed meal ration which contained the larger amount. Likewise, nitrogen storage was higher on the high protein ration but the results were not consistent. Nitrogen intake on both rations was above what might be considered as optimum levels.

Literature Cited

Blizzard, W. L. and Bruce R. Taylor. 1940. Oats and Cottonseed Cake Show up Well in Fattening Rations. Report of the Agr. Exp. Sta. of the Oklahoma A. & M. College, pp. 53–54.

Briggs, Hilton M. 1941. Fattening Lambs on Corn and Cottonseed Meal and on Alfalfa and Prairie Hays. Oklahoma Exp. Sta. Bul. B252.

Briggs, H. M. and V. G. Heller. 1940. The Effect of Adding Blackstrap Molasses to a Lamb Fattening Ration, Jour. Agr. Res. 60: 65–72.

Forbes, E. B., 1915. A Metabolism Crate for Swine. Ohio Agr. Exp. Sta. Cir. 152, pp. 75–85, illus.

———, Winifred W. Braman, Max Kriss, R. W. Swift, Alex Black, Donald E. Frear, O. J. Kahlenberg, F. J. McClure, and Le Roy Voris. 1933. The Associative Efforts of Feeds in Relation to the Utilization of Feed Energy. Jour. Agr. Res. 46: 753–770.

Kuhlman, A. H. and W. D. Gallup. 1940. Cottonseed Meal Tested as a Source of Carbohydrates. Report of the Agr. Exp. Sta. of the Oklahoma A. & M. College, p. 72.

———, Earl Weaver, W. D. Gallup, Andrew Nalbandov. 1936. Performance of Dairy Cows on Unusual Calcium-Phosphorus Ration. Proc. Amer. Soc. Animal Production, pp. 55–57.

Maynard, Leonard A. 1937. Animal Nutrition. McGraw-Hill Book Co. Inc. New York and London, pp. 138–140.

Morrison, F. B. 1936. Feeds and Feeding, A Handbook for the Student and Stockman. Ed. 20 Unabridged, 1050 pp., illus. Morrison Publishing Co., Ithaca, N. Y.

Snedecor, George W. 1937. Statistical Methods Applied to Experiments in Agriculture and Biology. 341 pp., illus. Iowa State College Press, Ames, Iowa.

LENGTH OF FEEDING PERIOD AND NUMBER OF ANIMALS REQUIRED TO MEASURE ECONOMY OF GAIN IN PROGENY TESTS OF BEEF BULLS[1]

BRADFORD KNAPP, JR.,[2] RALPH W. PHILLIPS,[2] W. H. BLACK,[2] AND R. T. CLARK[3]

U. S. Department of Agriculture and Montana Agricultural Experiment Station

TWO questions that are frequently raised in connection with record-of-performance tests of the progeny of beef bulls are:

(1) How long a feeding period is required to adequately test steers for efficiency of feed utilization and to measure carcass quality?

(2) How many steers are required to measure the transmitting ability of a bull?

Some data have been accumulated in connection with record-of-performance work at the U. S. Range Livestock Experiment Station at Miles City, Montana, which help to answer these questions.

Material and Methods

The data used in this study were collected on 62 steer calves, born in 3 different years. They were sired by 3 Hereford bulls and were out of registered or high-grade Hereford cows. The calves were weaned at an average age of approximately 180 days and were placed in individual feeding stalls to measure efficiency of feed utilization. The steers were fed until they weighed approximately 900 pounds, and the feeding period required to reach this weight varied from year to year. The periods were 356, 293, and 306 days, respectively, in the three years during which these data were collected. Individual feed and weight records were kept for each 28-day period.

Analyses of variance and covariance, as described by Snedecor (1937), were used in determining the significance of difference between the progeny of the sires. A method described by Hankins and Titus (1939, pp. 465–468) was used to determine the regression of efficiency of gain with increasing weight.

The necessary mean difference was computed by rearrangement of the "t" formula as follows:

[1] Based on work conducted cooperatively by the U. S. Department of Agriculture and the Montana Agricultural Experiment Station.

[2] Bureau of Animal Industry, Beltsville, Md.

[3] Montana Agricultural Experiment Station, Bozeman, Montana.

$$(M_1 - M_2) = ts\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

where $(M_1 - M_2)$ is the mean difference, n_1 and n_2 are number of individuals in the two groups, s is the pooled standard deviation of the 3 groups, and t is the necessary ratio of a deviation to its estimated standard error for statistical significance.

Data and Discussion

Length of Feeding Period

The data used in this study were collected during feeding periods ranging from 293 to 356 days. If differences between sire groups can be demonstrated with a shorter feeding period, there would be a considerable saving in time required to make records available for use in evaluating sires and in the labor and other costs involved in experimental feeding. If significant differences could be demonstrated with a period approximately half as long as those used, data obtained for any period between these two extremes should be adequate. Consequently, a period of 168 days was chosen. This includes six 28-day periods.

The average efficiency of feed utilization (gain per 100 lbs. T.D.N.[4]) for each of the sire groups is shown in table 1, for both the 168-day and the entire feeding period. Efficiency was lower for the entire period than for the 168-day period. It should be noted that steers sired by bull B made more efficient gains during both periods than the progeny of A and C.

TABLE 1.—AVERAGE EFFICIENCY OF FEED UTILIZATION IN PROGENY GROUPS

Bull		Number of steers	Pounds of gain per 100 pounds T.D.N. consumed	
Designation	No.		168-day period	Entire feeding period*
A	20	31	19.73	17.86
B	54	18	20.87	19.44
C	113	13	20.03	17.77

* Average feeding periods for all bulls in each of 3 years were 356, 293 and 306 days.

Calves sired by C were slightly more efficient during the 168-day period than those sired by A, but were slightly less efficient over the entire period. This point is discussed in detail later.

An analysis of variance on the data collected over the entire period indi-

[4] T.D.N. computed from tables in Morrison (1936).

cated that highly significant differences existed between the progeny of the 3 sires ($P \leqq .01$). A similar analysis of the data for the 168-day period did not show significant differences between sire groups ($P \geqq .05$).

Black and Knapp (1936) point out that weaning weight is one of the conditions that should be held constant when measuring efficiency of feed utilization. Under range conditions existing at Miles City this condition could not be met, and this seemed to be a possible explanation for the lack of significant differences between sire groups for the 168-day period. Corrections were therefore made for the differences in initial weight, by the use of covariance. After this adjustment to a constant initial weight, the differences between the progeny groups for the 168-day period were found to be significant ($P = .01$). Thus, it seems that under the conditions of this test, a 168-day feeding period or any period of time between 168 days and 300 days was sufficient to demonstrate differences between sires, providing adjustments were made for differences in initial weight.

Another approach to the problem of length of feeding period can be made through the use of the method of analysis described by Hankins and Titus (1939). This method, in brief, is to fit, by the method of least squares, the regression of mean weight with efficiency by periods. From this regression, the expected efficiency at any mean weight may be calculated. The regressions of the progeny of the 3 bulls are shown in figure 1. Between body weights of 300 to 600 pounds there is little difference in the levels of the progeny of the 3 bulls, but from about 600 to 900 pounds the lines of regression diverge so that considerable difference is noted. It was noted in table 1 that the progeny of bull C were more efficient than those of A for the 168-day period but not for the entire period. From figure 1 it is possible to explain this deviation. The progeny of bull C showed a much greater loss in efficiency with increased weight than did the progeny of A. Thus during the first portion of the feeding period, with a high initial efficiency, the calves of C appeared to utilize feed more efficiently than during the later part of the feeding period. It is interesting to note the observations of the feeder of these calves. He felt that the calves by B did better near the end of the feeding period than the progeny of the other two bulls.

The total length of feeding period must consist of enough periods to determine this regression of efficiency and mean weight, that is, there must be enough points to definitely establish the true slope of this regression. A minimum of 5 or 6 periods would be required. Therefore, with carefully conducted experiments, and using 28-day periods, a total feeding period of 140 days or more would be required to determine efficiency of the animals on test by this method.

The shorter feeding period would affect the quality of carcasses as meas-

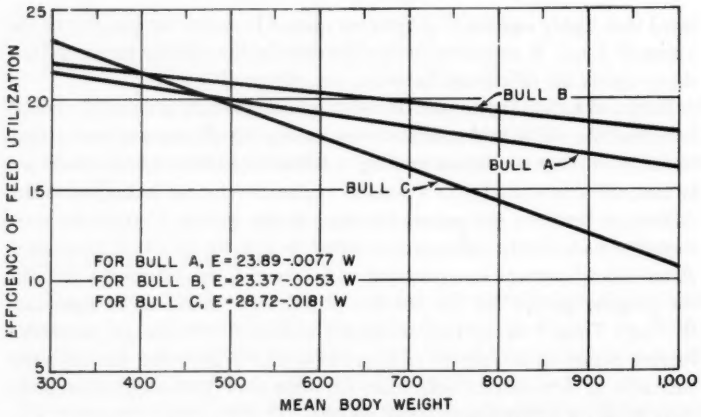

Figure 1. Regressions of efficiency of gain with mean weight of animals in the progeny of three Hereford bulls. Efficiency of gain is expressed as the pounds of gain per 100 pounds T.D.N. consumed, and body weight is given in pounds.

ured by carcass grade and since quality of product is important, a correlation study was made of the factors which affected carcass grade on the same 62 steers. Since finish is one of the important factors that determines grade, it is obvious that cattle on feed for longer periods would grade higher because of the greater amount of fat in the carcass. It was found that initial weight and total gain on feed accounted for approximately 80 per cent of the variation in carcass grade ($R = 0.892$). This is in agreement with the suggestion made by Black and Knapp (1936) that variations in inherited carcass quality could be measured best in a weight constant population. Multiple regression factors of carcass grade for initial weight were +0.1120 per pound initial weight and +0.0671 per pound for total gain. These indicate that a change of slightly over one market grade would be expected for each 100 pounds change in initial weight and approximately 2/3 of a grade for each 100 pounds change in total gain. This observation is in line with the results reported by Hankins and Burk (1938).

The use of a shortened feeding period would not be desirable from the standpoint of producing market cattle. However, it might be necessary in order to make possible the selection of bulls for breeding use in the year following that in which they were used to sire the steers being tested. Steers could be continued on test to obtain additional information, if this were desired for any reason. If not, the individual feeding could be discontinued and the steers fed to market finish in groups, thereby eliminating the expense of individual feeding.

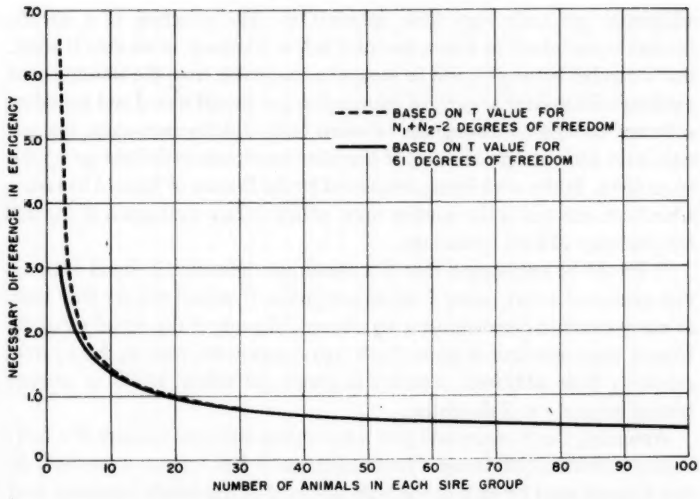

Figure 2. Necessary differences in efficiency of gain to be significant (P = .05). Necessary differences in efficiency are given in pounds, and indicate differences in pounds gained per 100 pounds T.D.N.

Number of Animals Required for Testing

The number of offspring required to test a bull is important. If work of this type is to be done it should be on numbers that are sufficiently large to be reliable in indicating differences. One approach to the problem is to determine the necessary differences between groups by the use of a pooled standard deviation of efficiency of animals fed under similar conditions. This is accomplished in the manner described by Hetzer and Brier (1939). By analysis of variance, the pooled standard deviation between steers from the same sire was used to determine the differences in efficiency that would be necessary to indicate significant differences in efficiency of feed utilization. The mean differences between groups of animals necessary to indicate significant differences ($P \leqq .05$) are shown in graphic form in figure 2. The solid line is based on calculations in which the t value for 61 degrees of freedom was used. The broken line is based on calculations in which the t value for n_1+n_2-2 degrees of freedom was used. In either case the curves break sharply between 5 and 15 animals, the sharpest break being between 5 and 10. That is, there is a rapid increase in information gained for each animal added, up to 5. From this point on, the information gained from each successive animal becomes relatively less, and after reaching 15 animals, each

additional one adds very little information. The selection of a specific number upon which to base a test of a bull is arbitrary, of course. It seems that a number between 6 and 10 would be acceptable from the standpoint of yielding a fairly large amount of information per animal tested and including sufficient animals to distinguish between bulls if differences exist. Six animals leave little margin of safety if there are any losses in the test group due to accident. In the work being conducted by the Bureau of Animal Industry, 8 has been selected as the number upon which to base evaluation of the bull for efficiency of feed utilization.

It should be emphasized that if a significant difference is found between two groups of steers, using 8 steers per group, it would require four times as many steers to demonstrate a significant difference if the actual mean difference were only half as great. Lush (1931) concluded that, in dairy cattle, relatively little additional accuracy is gained per animal added in progeny testing beyond 5 to 8 daughters.

Assuming that 8 steers will give a reasonably accurate measure of a bull's ability to transmit efficiency of feed utilization, it is of interest to see how the first 8 steers sired by each of the bulls involved in this study compared with the remaining steers. The data are given in table 2 for the first 8 steers, the remaining steers, and for these two groups combined.

TABLE 2.—AVERAGE EFFICIENCY OF FEED UTILIZATION OF FIRST 8 STEERS, REMAINING STEERS, AND ALL STEERS SIRED BY EACH OF 3 BULLS

Bull		Total number of steers	Pounds of gain per 100 pounds T.D.N. consumed		
Designation	No.		First 8 steers	Remaining steers	All steers
A	20	31	17.81	17.88	17.86
B	54	18	19.33	19.52	19.44
C	113	13	17.95	17.47	17.77

The necessary mean differences to show significant differences between bulls have been calculated and are shown in table 3. Using the figures in this table, it can be shown that the first 8 progeny of bull B are superior to those of bull A ($P \leqq .05$), but the difference between bulls B and C is not statistically significant. Considering all the steers, it can be shown that B is superior to both A ($P \leqq .01$) and C ($P \leqq .01$). The differences between the bulls were indicated by the first 8 progeny of each. Information on additional steers served to confirm these results, and with added numbers, the statistical significance of the differences was increased, as would be expected. The

TABLE 3.—MEAN DIFFERENCES NECESSARY FOR SIGNIFICANT ($P \leq .05$) DIFFERENCES IN EFFICIENCY OF FEED UTILIZATION BETWEEN GROUPS OF STEERS. NUMBERS IN THE TWO GROUPS ARE REPRESENTED BY n_1 AND n_2. FIGURES GIVEN REPRESENT DIFFERENCES IN POUNDS OF GAIN PER 100 POUNDS T.D.N.[1]

n_2 \ n_1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	30
2	3.04	2.77	2.69	2.54	2.48	2.43	2.40	2.37	2.35	2.32	2.29	2.28	2.26	2.25	2.22
3		2.48	2.32	2.22	2.15	2.09	2.05	2.02	2.00	1.96	1.93	1.91	1.89	1.88	1.84
4			2.15	2.04	1.96	1.90	1.86	1.82	1.80	1.75	1.72	1.70	1.68	1.66	1.62
5				1.92	1.84	1.78	1.73	1.69	1.66	1.62	1.58	1.56	1.53	1.52	1.47
6					1.75	1.69	1.64	1.60	1.57	1.52	1.48	1.45	1.43	1.41	1.36
7						1.62	1.57	1.53	1.50	1.44	1.41	1.38	1.35	1.33	1.27
8							1.52	1.47	1.44	1.39	1.35	1.31	1.29	1.27	1.21
9								1.43	1.39	1.34	1.30	1.26	1.24	1.22	1.15
10									1.36	1.30	1.26	1.22	1.20	1.18	1.11
12										1.24	1.19	1.16	1.13	1.11	1.04
14											1.15	1.11	1.08	1.06	.98
16												1.07	1.04	1.02	.94
18													1.01	.99	.90
20														.96	.88
30															.78

[1] $S = 1.5177$. $t = 2.00$ where $P \leq .05$.

figures in table 3 would not apply directly to any other population, since they are based upon the variation observed in the specific animals used in this study. However, they should be useful in indicating the approximate differences necessary to show significant differences between groups of similar animals maintained under similar conditions.

Summary

Data on 62 individually fed steers were analyzed to obtain information on the length of feeding period required to measure efficiency of feed utilization and on the number of steers upon which records should be obtained to adequately test a bull's transmitting ability.

A feeding period of 168 days was found to be sufficient to indicate differences between progeny groups, provided the data were adjusted for differences in initial weight. This finding was based on an analysis of variance and covariance. If the method of least squares were used to determine the regression of mean weight with efficiency, at least 5 or 6 twenty-eight-day periods would be necessary to determine the slope of the regression.

Carcass grade would be affected by the use of a shorter feeding period. Approximately 80 per cent of the differences in carcass grade could be accounted for by differences in initial weight and total gain while on feed. An increase of slightly over one market grade would be expected for each 100 pounds increase in initial weight, and 2/3 of a grade for each 100 pounds increase in total gain.

The number of individually fed steers necessary to give a reasonably good test of a bull's ability to transmit efficiency of feed utilization is approximately 8. Beyond this number little additional information is gained per steer added.

Literature Cited

Black, W. H., and Bradford Knapp, Jr. 1936. A Method of Measuring Performance in Beef Cattle. Amer. Soc. An. Prod., Proc. 29: 72–77.

Hankins, O. G., and L. B. Burk. 1938. Relationships among Production and Grade Factors of Beef. U. S. Dept. Agric. Res. Bull. 665, 39 pp., illus.

Hankins, O. G., and Harry W. Titus. 1939. Growth, Fattening, and Meat Production. Food and Life, Yearbook of Agriculture 1939, pp. 450–468.

Hetzer, H. O., and G. W. Brier. 1939. Estimates of Mean Differences Necessary for Significance between Pigs in Group Feeding Experiments. Amer. Soc. An. Prod., Proc. 1939: 157–161.

Lush, Jay L. 1931. The Number of Daughters Necessary to Prove a Sire. Jour. Dairy Sci. 14: 209–220.

Morrison, F. B. 1936. Feeds and Feeding. 20th ed. Morrison Publishing Co., Ithaca, N. Y.

Snedecor, George W. 1937. Statistical Methods. 341 pp., illus. Collegiate Press, Ames, Iowa.

NON-RANDOMNESS OF VARIATIONS IN DAILY WEIGHTS OF CATTLE

G. A. Baker[1] and H. R. Guilbert[2]
University of California

Introduction

VARIATIONS in live weight, particularly in cattle, as they influence the accuracy of feeding experiments have long been recognized. As a result of the investigations of Armsby (1917), Benedict and Ritzman (1923), Forbes and Grindley (1923), and Lush *et al.* (1928) the general recommendation and practice in cattle feeding trials has been to weigh the individual animals on 3 consecutive days at the beginning and end of the trial and to include at least 10 animals per lot. Lush *et al* (1928) indicated that under uniform environmental conditions equal accuracy could be obtained by single weights on 30 steers as by 3 consecutive daily weights on 10 steers. It was assumed in the statistical treatment of the data that daily weights were independent. Maymone and Sircana (1930) demonstrated that the variations in daily weights of dairy cows for periods less than 75 days could be represented by a straight line trend plus an oscillatory part that was cyclic in nature.

This paper is based on investigations of the distributions of deviations from linear trend in daily cattle weights, the randomness in the variation of consecutive daily weights of cattle, the relation between variations of individuals subjected to uniform conditions, and the relation of variations in daily weights to daily range of temperature.

Experimental

The data consist of 69 consecutive daily weighings on 7 heifers and 1 steer, all yearlings, made in 1924 by one of us (H.R.G.). During the first 33 days the animals were weighed daily at 11:20 a.m. and allowed free access to water at all times. They were fed about 7 a.m. and 5 p.m. During the succeeding 32 days they were weighed at 6:45 a.m. before feeding and watering. The water was shut off at 7:00 p.m. each evening. The last four days the animals were weighed under the same conditions as at the beginning.

The cattle were fed all the alfalfa hay they would eat from the beginning and were started out on 3¾ pounds of rolled barley per head, per day. This amount was gradually increased to a little over 7 pounds at the end of the first 30-day period, and on the 24th day ½ pound of cottonseed meal was

[1] Junior Statistician in the Experiment Station, Davis, Calif.
[2] Associate Professor of Animal Husbandry and Associate Animal Husbandman in the Experiment Station, Davis, Calif.

added. During the second period raisin pulp was substituted for a part of the barley, 10 days being taken to change to equal parts of rolled barley and raisin pulp. The ration was then increased until they were consuming at the last, 5 pounds of rolled barley, 5 pounds of raisin pulp, and 1 pound of cottonseed meal. The feeds were all mixed together and fed in a feed bunk.

The gradual changes made in the ration did not influence in any measurable way the day-to-day behavior of the weights.

The first three days, the thirty-fourth and thirty-fifth days are adjustment

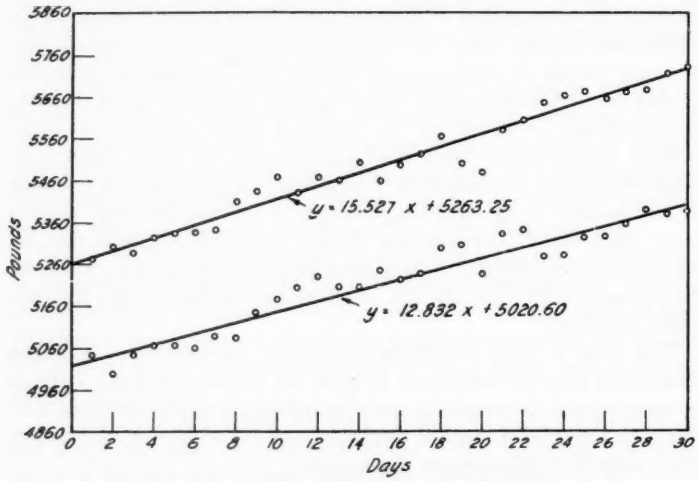

Figure 1. Total Daily Weights of Eight Yearling Cattle for Two Thirty-day Periods with the Corresponding Least-square Lines.

periods and the last period is too short to be of value in this study and are, therefore, omitted from the discussion. This leaves two sets of thirty consecutive daily weights.

Figure 1 shows straight lines fitted to the totals for all eight animals for each of the two 30-day periods. The straight lines seem to fit satisfactorily except for cyclic or oscillatory effects. Since the rate of increase was slightly greater in the second period than in the first, a straight line over a 60-day period would not be acceptable.

On the basis of the finding presented in figure 1 it was decided to fit straight lines to the weights of each of the eight animals for each of the 30-day periods. The corresponding weights read from the fitted equations are called the adjusted weights. The differences between the observed weights

and the adjusted weights—that is, observed weights minus adjusted weights—are called the deviations from linear trend.

The deviations from linear trend for the first period, grouping all 240 together, are normal as tested by the usual Chi-square frequency distribution test, with a standard deviation of 8.64 ($P = .4$). The deviations for the second period are not normal by the Chi-square test ($P = .007$). The standard deviation is now 6.97, but the whole distribution is slightly skewed, piled up in the middle and heavy on the tails. These values of the standard deviations agree with those given by Lush *et al.* (1928).

The numbers of plus and minus deviations are about the same for each period. There are 117 negative and 123 positive deviations for the first period; 118 negative and 122 positive deviations for the second. These facts suggest that in both periods we can consider that positive and negative deviations are equally likely or that the probability of each is $\frac{1}{2}$.

The distribution theory of runs has long received attention and has recently been discussed in some detail by Mood (1940). The order of the deviations from linear trend were compared with what would be expected in random sampling from a population in which the probability of positive and negative deviations is, for each, $\frac{1}{2}$. A run means the number of deviations of like signs—for instance, the deviations plus, minus, minus, plus, plus represent runs of 1, 2, and 2. The probability of a run of length r in sampling from a population with equal numbers of positive and negative deviations and with an indefinitely long sequence of draws is $\frac{1}{2}^r$.

If the indefinitely long sequence is broken up into subsequences, the probabilities of short runs are somewhat increased, whereas the probabilities of long runs are decreased. With subsequences of 30 the probabilities are only slightly changed, as shown by empirical sampling from a normal population. These empirical probabilities are as follows: .508, .268, 126, .044, .027, .014, .007, .002, .002, .000, .002 for runs of length 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, respectively, based on 564 runs. Deviations from linear trend can be expected to show a spurious negative correlation because the constants of the fitted straight lines are computed from the data. Thus if all deviations tend to be all one way from the "true" trend, some must necessarily be of the opposite sign as measured from the computed trend. The spurious correlation would tend to increase further the number of short runs and decrease the number of long runs. This spurious correlation will be small because the weights are only given to the nearest $2\frac{1}{2}$ pounds. What negative correlation there is will enhance the significance and importance of subsequent findings of positive correlations. Thus it is conservative to use $\frac{1}{2}^r$ as the probability with which to compare actual observed runs of deviations.

Data in table 1 show that short runs are less frequent and long runs are more frequent for the data than would be expected in random sampling from a population with equal numbers of positive and negative deviations.

TABLE 1.—COMPARISON OF OBSERVED RUNS OF DEVIATIONS FROM NORMAL WEIGHTS WITH A HYPOTHESIS OF RANDOM SAMPLING FROM A POPULATION WITH EQUAL NUMBERS OF POSITIVE AND NEGATIVE DEVIATIONS*

Run	Observed	Theoretical
1	91	102.0
2	47	51.0
3	25	25.5
4	11	12.8
5	17	6.4
6	6	3.2
7 and greater	7	3.1
Totals	204	204.0

* $x = 26.68$. d.f. $= 6$. $P = .0002$

The correlation between pairs of consecutive daily deviations were treated by the analysis of covariance to determine the extent to which the correlation is due to day-to-day changes in environment and to individual animal differences. Forming pairs in the exact order obtained we get an overall correlation of .23 with 224 degrees of freedom, a correlation between means of the eight deviations for a day of .14 with 28 degrees of freedom, and a correlation due to individual differences of .26 with 196 degrees of freedom. The first and last of these correlations are significantly different from zero which checks with table 1 but none of them are significantly different from each other so that in this experiment, so far as we can tell, the correlation due to day-to-day changes in environment is of about the same order as the correlation due to individual animal differences. This would not necessarily be true in other experiments.

The regression equation of x_2, a second daily deviation, on x_1, a first daily deviation, is $x_2 = .23x_1$. The data could be divided into sets of three and the regression equation of the third daily deviation written in terms of the first two daily deviations. The predicability of the third deviation would be increased to 28 per cent. This process could be continued, but the effect of adding more daily deviations in the estimating equations would quickly damp out.

The extent of variations in the deviations of daily weights due to changes which affect all animals alike and to changes that are individual with each animal was studied by analysis of variance. In each period 16 degrees out of

a total of 240 is used in determining the constants of the linear trends. This leaves 28 for between days and 196 for individual differences of the various animals. The corresponding mean squares for the first period are 127.23 and 67.05; for the second period are 98.50 and 41.47. Hence F for the first period is 1.90 and for the second is 2.38. Both values of F are significant ($P < .01$). Thus the day-to-day variations in environment are about twice as important per degree of freedom as individual animal differences in producing daily variations in the deviations from trend and it follows that correlation exists between the deviations in daily weights for the different animals.

The extreme range of maximum temperatures for the entire first period was 81° to 55° F and the mean maximum was 68°. For the second period the range of maximum temperatures was 69° to 45° and the mean 59°. The deviations of the totals as presented in figure 1 were compared with the daily range in temperature. The correlation coefficients for the two periods are .43 and $-.01$. These should be compared with .19 for significance. The first is significant ($P = .02$), but the second is not. Much more extensive and detailed data are necessary to show exactly how deviations in weight are affected by environmental changes.

Discussion

The variations in daily weights of cattle can be divided into two parts. The first part is due to environmental conditions that affect all animals in the same way. These data show that the effects of environment can be made much less by keeping the cattle confined for 12 hours without feed and water before weighing. The standard deviation of the deviation distribution was reduced by 19 per cent and the frequency of small deviations was much increased by the use of shrunk weights. These environmental conditions induce a correlation between the daily weights of cattle kept under the same conditions. This correlation can be obviated if conditions can be made sufficiently uniform. One of the most easily observed day-to-day changes is range in temperature. Range in temperature was positively correlated with changes in weight during the first period when the animals had free access to water and were weighed about noon but was not correlated with changes in weight when the animals were confined all night and weighed before feeding and watering.

The second part of the variation in daily weights of cattle is due to individual characteristics of the animals and can not be obviated by control of environmental conditions. The data presented confirm those of Maymone and Sircana (1930) which showed that consecutive daily deviations from linear trend of cattle under uniform conditions are correlated. The fact of

this correlation due to individual characteristics of the animals is very important from the standpoint of feeding trials. Let us neglect the possibility of correlation between the daily weights of the different animals since this correlation theoretically could be reduced to zero by making the conditions sufficiently uniform. Let x_1, x_2, x_3 be the deviations in the daily weights for a single animal. Then the expression $(x_1+x_2+x_3)^2/3$ summed for a great number of different sets and divided by the number of sets would be the variance of the mean of the three daily weights. Take $r_{12}=.23$, $r_{13}=.16$, and $r_{23}=.23$ which are as good estimates of these correlations as we can get from the data, then the variance is $4.20\sigma^2/9$ where σ^2 is the common variance of x_1, x_2, x_3. Hence for the ten animals the variance of the mean is $4.24\sigma^2/90$. If the daily weights, x_1, x_2, x_3 were uncorrelated, the variance would be $\sigma^2/30$. The first variance is 141 per cent of the second. In other words, 14 animals were required to get as good results as was expected with 10.

These data indicate a relatively greater increase of accuracy accruing from addition to the number of animals than to increasing the number of weights for each animal. Thus under uniform conditions single weights on 30 animals should give equivalent accuracy to 3 consecutive weights on 14 animals. This is significant in view of the increasing tendency to conduct feeding trials in cooperation with cattlemen where larger numbers of animals are available but repeated weighings are frequently impracticable.

The importance of an adequate fore period for adjustment of the animals and uniform time of weighing to minimize environmental factors are emphasized.

The reduction of deviations and practical elimination of temperature influence on weight variation by 12 hour shrunk weights in this experiment are worthy of consideration in feeding trials and particularly in range and pasture experiments. Shrunk weights as obtained in this experiment do not interfere significantly with feeding schedule or gains and give final weights more consistent with selling weights. Under pasture and range conditions, it is difficult to obtain comparable so-called "full weights" at consecutive weighing periods.

Summary

Statistical analyses are presented for 69 consecutive daily weighings of 8 head of yearling cattle. During the first half of the period the animals had free access to feed and water and were weighed at 11:20 a.m.; during the last half, water was shut off at 7:00 p.m. and the cattle weighed before feeding at 6:45 a.m. The analyses confirm the report of Maymone and Sircana (1930) that cyclic variations may occur in the day-to-day deviations of cattle weights. On the basis of the data presented three daily weights of 14 animals

would be required to obtain the accuracy assumed for 3 daily weights, independent in a probability sense, for 10 animals.

Some correlation was shown to exist between deviations of the various animals due to environmental conditions. When the animals were allowed free access to water and the weighings were made near mid-day, the deviations in daily weights were positively correlated with daily temperature range. When the animals were without feed and water at night and the weights taken early in the morning, no significant correlation between deviations in daily weights and daily temperature range was found.

These findings indicate that in feeding trials an adequate fore period for adjustment is necessary and that environmental effects can be lessened by weighing at the same time of day and by using shrunk weights. The shrunk weights of the second period did not interfere with feeding or rate of gain, and gave weights that were less variable and more consistent with selling weights. The findings also indicate that a relatively greater increase in accuracy results from using more animals in each group in an experiment than from increasing the number of weights obtained per animal.

Literature Cited

Armsby, H. P. 1917. The Nutrition of Farm Animals. Macmillan Company, pp. 1–743.

Benedict, F. G. and E. G. Ritzman. 1923. Undernutrition in Steers: Its Relation to Metabolism, Digestion, and Subsequent Realimentation, pp. 1–333. Published by the Carnegie Institution.

Forbes, E. B. and H. S. Grindley. 1923. Bulletin of the National Research Council No. 33, Vol. 6, Part 2. pp. 1–54.

Lush, J. L., F. W. Christensen, C. V. Wilson and W. H. Black. 1928. The Accuracy of Cattle Weights. J. Ag. Res. 36: 551–580.

Maymone, B. and C. Sircana. 1930. Die normalen Lebendgewichtsvariationen bei Rindern. Zeit f. Zücht. Reihe B., 18: 63–108.

Mood, A. M. 1940. The Distribution Theory of Runs. The Annals of Mathematical Statistics, 11: 367–392.

THE EFFECT OF NUMBER OF DAILY MILKINGS UPON PERSISTENCY OF MILK PRODUCTION

I. LUDWIN[1]
Washington, D. C.

PERSISTENCY of lactation has been defined by Gaines (1927) as the degree with which the rate of milk secretion is maintained as lactation advances. This character is of interest to the dairyman because a persistent cow would not only give a high total yield but could do so without reaching a very high maximum.

The object of this study is to investigate the effect of frequency of milking upon persistency. If there is a direct effect such knowledge would be of interest to dairymen. Information concerning this matter would also be useful in further studies of persistency, especially in herds where cows are milked a different number of times daily in various lactations. This study is not concerned with length of lactation but investigates the effect of continued twice, three-time or four-time daily milking upon persistency from the third to the ninth month of the lactation.

Woodward (1931) showed by lactation studies and by alternating the frequency of milking in successive forty-day periods, that cows were more persistent when milked more frequently. Hansen and Joshi (1934), in a study of fourteen Indian and Crossbred cattle (commercial herd milked two and three times per day), also concluded that increasing frequency of milking increased persistency of milk yield.

There are two essentially different views of persistency. Results of studies may be given entirely different interpretations depending upon which of these two general views is adopted. Persistency may refer to:

1. Rate of decline in milk flow without regard to level of production. The lower the rate of decline the more persistent the animal. Persistency and level of production are necessary to measure an animal's milk producing ability from this point of view.

2. Rate of decline with respect to level of production or any ratio measure (i.e. one portion of the lactation compared with another portion). Such a measure of persistency gives animals making the same proportionate decline from different peaks the same persistency value. Level of production is also necessary here to estimate total production.

[1] The advice of Drs. G. E. Dickerson and L. J. Cole is greatly appreciated and counsel by Drs. J. Torrie and C. Eisenhart of the University of Wisconsin with regard to the statistical techniques used is also acknowledged.

These data were made available for study through the courtesy of the Holstein-Friesian Association of America. Every assistance possible was extended by Mr. H. W. Norton, Jr., Superintendent of the Advanced Registry.

The author is Statistical Analyst, Navy Department, Washington, D. C. (now on leave for military duty) and was formerly a graduate student at the University of Wisconsin.

Measures of both these general types have been used in various studies of persistency. A review of this subject has been presented by Johansson and Hansson (1940).

For the present study three simple measures of persistency were chosen. These measures were applied to each of the 728 lactations studied. The measures used are:

$$\text{Measure No. 1} = \frac{(3+4+5\text{th month's yield}) - (7+8+9\text{th month's yield})}{12}.$$

This estimates the average monthly decline in milk production. It can also be considered an estimate of slope with sign reversed. This is a type 1 measure.

$$\text{Measure No. 2} = \frac{\text{Measure \#1}^2}{\text{Aver. monthly yield}}.$$

This gives an expression of average decline in relation to average yield and is a type 2 measure.

$$\text{Measure No. 3} = \frac{\text{Total yield (sum of 7 months)}}{\text{Yield of last three months}}.$$

This is a ratio measure which is also of type 2.

Material and Methods

Holstein-Friesian A.R.S.O. records were selected from Advanced Register Yearbooks, volumes 36–49 inclusive. These are the original records sent in to the Association showing yield at each daily milking, test, etc. The following criteria were required of every record used in this study: (a) Every record was at least 305 days in length; (b) the cow must have been milked the same number of times daily for at least the first nine months after calving except for the first 45 days;[3] (c) the cow must have had at least two records both made in the same herd; (d) each of the two records under (c) must have been made under a different number of daily milkings; (e) records must be capable of fitting a composite comparison. These were

[2] $y = a + bx$ (A)
$y = Ae^{kx}$ (B)

Gaines, in a personal communication, has pointed out that measure No. 2 is an estimate of k in equation (B) which may be shown as follows. If equations (A) and (B) are fitted to the same set of observations the slope of equation (A) will be the same as equation (B) at some one point. As an approximation this point may be taken as at $\bar{x}$ (the mean of x), that is: $kAe^{k\bar{x}} \cong b$. As a further approximation it may be taken that equation (B) goes through $\bar{y}$ (the mean of y) at $\bar{x}$, that is $Ae^{k\bar{x}} \cong \bar{y}$ Hence, $k\bar{y} \cong b$ or $k \cong b/\bar{y}$ ($\cong$ means approximately equal).

[3] Advanced registry regulations permit any number of milkings daily (not over four) for the first 45 days of the official test regardless of the frequency of milking thereafter. In most cases, however, the cows were milked the same number of times daily throughout the lactation.

the only criteria used and since no records were examined before selection there was no way of discarding or choosing any particular one. In all, 728 records on 364 cows were obtained.

Uncorrected milk yields have been used throughout the present study. A study bearing on the use of Fat Corrected Milk rather than uncorrected milk yield has been made by Edwards (1936), who considered the influence of advance in lactation upon gross efficiency of milk production. His study is based on 1176 ROM records of the English Jersey Cattle Club and he concludes that "with advance in lactation there is a change in the composition of the milk and yet the decline in the total energy of the milk secreted follows at a higher level the same course as the decline in the actual volume of the milk." It may be assumed that a similar situation is true in the Holstein-Friesian breed since no evidence to the contrary is known.

The method of analysis used in this study was designed in an attempt to remove the effect of individuality, age and herd environment, leaving the effect of frequency of milking the primary remaining variable.

If number of daily milkings has no effect on the absolute rate of decline in milk yield two or more lactation curves of the same cow made under different frequencies of milking, other factors being equal, would be parallel. A difference in rate of decline would be shown by a tendency of the two curves to converge or diverge with advancing lactation. In order to test this, records of cows in different herds were paired in such a way as to give in each case a "composite comparison." Such pairing would tend to eliminate the effect of age of cow, herd environment, and individuality of a cow, with respect to persistency. The possibility of an interaction between frequency of milking and age of cow has not been eliminated. An interaction or differential response would be due to the fact that increased frequency of milking when combined with increased age of cow might possibly give a different effect as compared with an increase of frequency of milking associated with a decrease in the age of the cow. The author knows of no grounds to expect such an interaction but the possibility should be mentioned.

To meet the conditions necessary for forming one composite comparison a cow with two lactation records in one herd at different frequencies of milking was paired with another cow in a different herd with two records at the same ages as the first cow but with frequency of milking at the respective ages reversed. This may be illustrated by the following example:

	Cow No. 17	Cow No. 36
Age at Calving	*Records made in herd A*	*Records made in herd B*
2 years	4X	3X
4 years	3X	4X

By averaging the respective monthly records of the two cows for 3X daily milkings, a mean 3X lactation curve is obtained. A mean 4X curve for these two cows is obtained in the same way. The graph of the mean lactation curves of such a group of four records constitutes the composite comparison.

Such composites may be set up for animals of any ages and for different milking frequencies. The effect of herd environment might be eliminated still further if pairs of cows meeting the requirements could be selected from the same herd but this was impractical since few such composite groups could be found.

Data and Discussion

In order to determine whether one curve of a composite comparison was affected more than its mate by age at calving, effect of pregnancy, season of calving, or time elapsed from calving to the beginning of the third full month of lactation, each of these factors was carefully examined.

Consideration of Age

The method of analysis requires that the two lactation curves of each comparison group (figure 1) be made at the same average age. When originally compared the cows were paired by age in years to their last birth date. This means that an animal from 24 to 35 months inclusive was considered two years old. In order to check more closely the accuracy of such pairing by years the age of each cow at calving was converted to age at the nearest month. The two age distributions (in months) for each comparison group were then tested for significant differences. No significant differences[4] were found to exist in age distribution between the two curves in any one of the three comparisons by the X^2 test. Age at calving was, therefore, effectively balanced in each group.

Effect of Pregnancy

Since stage of pregnancy is known to affect milk flow it follows that this factor must be considered in a study of the effect of frequency of milking. Cows which are milked 2X daily come into heat earlier than do cows milked 4X daily (Clapp, 1937). This agrees with the accepted idea that cows which are milked 2X daily are usually bred sooner after calving than those which are milked more frequently. Earlier conception associated with low frequency of milking might introduce real differences between the two curves of each comparison group. In only 17 cases (11 in 3X-4X and 6 in 2X-4X) of the 728 lactations in this study did conception occur within the first 80 days following parturition. Since it is well established that pregnancy has

[4] The terms, significant and highly significant, indicate levels of significance of $P = .05$ and .01, respectively.

little effect on milk flow until after the fifth month (Brody, *et al.*, 1923; Gaines and Davidson, 1926, 1926a, 1927) it can be concluded that time of conception was generally such as to place the fifth month of the gestation in the 8th or 9th month of the lactation at the earliest. In the 2×-3× comparison there were no pregnancies during the first 80 days of lactation al-

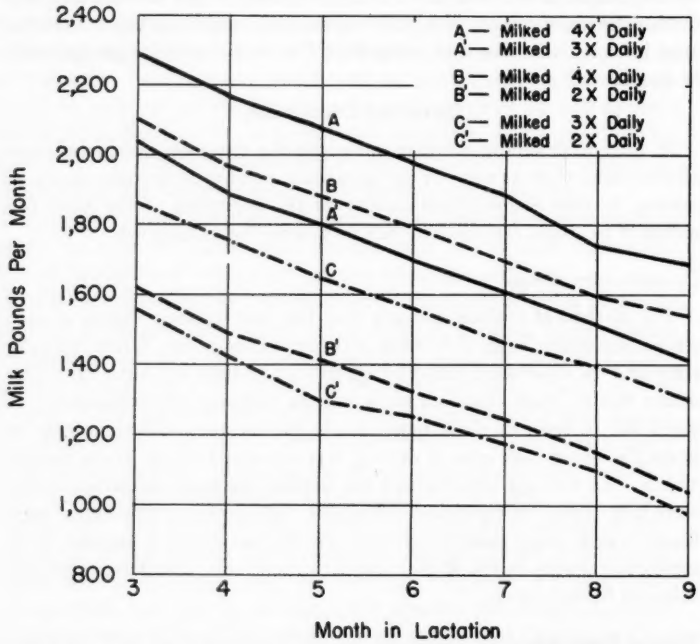

Figure 1. Effect of number of daily milkings upon decline in milk yield with advancing lactation. Lines A and A′ are based on 122 composite comparisons. (488 records on 244 cows.). Lines B and B′ are based on 22 composite comparisons. (88 records on 44 cows). Lines C and C′ are based on 38 composite comparisons, (152 records on 76 cows).

though there was a significant difference in distribution of service period length. Since this study includes only that part of the lactation from the 3rd to the 9th month the effect of pregnancy is considered to have exercised no important effect insofar as the results of this study are concerned.

No significant differences in the distributions of length of service period were found in the 2×-4× or the 3×-4× comparisons by either the X^2 or the *t* test. The distributions of service period length did differ significantly

in the 2×-3× comparison group. Contrary though it seems to be to general practice the same cows in this group conceived later when they were milked twice daily than when they were milked three times daily. The reason for this is not known.

Season for Calving

The number of cows calving in any months of the year for the 2× treatment of the 2×-3× comparison group did not differ significantly (X^2 test) from the number of cows calving in the 3× treatment of that same month. The same was true of the 3×-4× and the 2×-4× groups.

This evidence, while not critical (since two cows might calve in the same month under widely different feeding conditions in different parts of the United States), supports the view that season of calving was in all cases evenly distributed between treatments of each comparison group. Season of calving is therefore believed to be of negligible importance in affecting the results of this study. It need hardly be pointed out that cows on A.R. tests are generally well fed.

Time from Calving to Third Full Month

The portion of the lactation used throughout this study covers the period from the third to the ninth month inclusive. This comprises the major portion of the milk flow and should therefore show any important differences in persistency. The first month after freshening that included fifteen or more testing days was considered the first month of lactation.

There was no significant difference between the two curves of each comparison group in the distributions of number of days from calving to the beginning of the third month of the lactation. In other words, the two curves of each comparison group did not differ significantly from each other (X^2 test) in the number of days elapsed from calving to the beginning of the third full month.

The curves in figure 1, constructed directly from the composite comparisons, give a summary of the effect of increased number of daily milkings upon persistency. However this graphical method does not evaluate the data in a manner suitable for statistical analysis. The data were therefore submitted to an analysis of variance. The analyses were based on the monthly differences in milk yield between cow pairs, i.e. the difference due to the effect of treatment for each month within a composite comparison. The variation between months from the average difference was not found to be significant. This means that the curves did not depart significantly from parallel.

An analysis of variance based on actual monthly milk yield of individual

lactations (separate analyses were run for each group namely, 2×-3×, 2×-4×, and 3×-4×) showed that cows, months and treatments were highly significant sources of variation, and also that the interaction of months × treatments was in no case significant. This interaction shows that the variation of the different months from the mean of that treatment did not differ significantly due to treatment.

The slope of the lactation curve was not changed by number of daily milkings yet the total yield differed significantly between treatments. The interpretation is that more frequent milking causes the same absolute change in yield throughout the lactation (3rd to 9th month).

That the portion of the lactation curve studied here (3rd to 9th month) is best considered a straight line was determined by testing for non-linearity by the analysis of variance as described by Goulden (1939). The 728 records were sorted into seven age classes on the basis of age at time of calving. Each one of these age classes consisted of records mixed with reference to frequency of milking, i.e. each class was composed of records made under different frequency of daily milking conditions namely 2×, 3×, and 4×. The number of records in any one age class ranged from 221 to 41 with the classes progressively smaller with increasing age. These seven age groups were separately tested to find out whether there was a significant deviation of the array means from a fitted straight line after the between cow variation had been removed from within arrays. The remaining error term consists of the variation within months. No evidence of non-linear regression was found. The implication is therefore, that any measure of persistency applied to these data should be based on a linear relationship.

Results of Analyses of Measures Nos. 1, 2, 3

The results obtained by analysis of variance of the measures used agree with what would be predicted from figure 1 and a knowledge of the type of measure used. Measure No. 1 (ave. decline per month) in no case showed a significant difference between treatments. Measures No. 2 and 3 became significantly smaller under more frequent conditions of milking because of differences in level of yield, not because of differences in rate of decline.

Although these data were not gathered primarily for repeatability of persistency studies such indications as exist in these records show that there were no significant differences between cows in absolute rate of decline. An analysis of variation based on measure No. 1 in no case showed variation between cows to be significantly greater than the variation within cows. This result was obtained even after all cows (i.e. both records) were eliminated which had first lactations. An interesting point is that of the 728 records in this study 2.9% had ascending lactations and in no case were both

lactations of the same cow ascending. Gaines (1927) found 5.4% of the Guernsey records in his study to have ascending lactation curves.

Conversion Factors

It is of interest to compare the effect of frequency of milking for the portion of the lactation studied here with various conversion factors based on the entire lactation (table 1).

TABLE 1.—EFFECT OF FREQUENCY OF MILKING ON YIELD

Conversion made	Conversion factors*				
	Data in present study	(Rice) (1934)	Norton (1932)	Copeland (1934)	Woodward (1931)
2X–3X	1.26	1.20	1.20	1.21	1.20
3X–4X	1.17	1.15	1.19		
2X–4X	1.38	1.37	1.31		

* Copeland's data based on Jersey ROM records, Woodward's based on experimental work. All other columns based on Holstein-Friesian A.R. records.

Judging from these comparisons it appears that the data used in this were representative of A.R. data generally.

Discussion

A few points concerning the records used here should be considered. Objection to the data used and therefore to the conclusions may be based on the following points; feeding differences associated with frequency of milking practices, the elimination of cows having records under 305 days in length, the condition of the cow when milked more frequently, and shifting a cow into a different frequency of milking class after starting her lactation. Any one or all of these might exert a preferential effect upon one of the two treatment curves in a composite comparison.

There can be no final answer given to all of the above objections on the basis of the present study but it can be pointed out that the results obtained by applying the graphical method of analysis to the Mass. State College herd records[6] (where record selection was probably not so extreme as in the present study of A.R. records from many herds) were similar to the graphs shown in this paper in all cases. Also the three independent samples of A.R. data of this study (2X-3X, 2X-4X and 3X-4X) give similar results. The explanation is either that the variables involved in selection of the lactations had no important effect, or that in each case these variables had much the same combined average effect.

[6] Unpublished data; I. Ludwin.

Summary and Conclusions

The effect of frequency of milking upon persistency of milk production was studied by selecting 364 Holstein-Friesian A.R. cows, each having 2 records meeting certain conditions. These cows were then paired so that the effect of age, individuality, and herd environment were balanced so far as possible. The prime variable affecting milk production remaining in this type of analysis is frequency of milking. It is concluded that:

1. Persistency measured by actual rate of decline (slope) is not affected by frequency of milking. If a proportional measure of persistency is used then persistency is increased by more frequent milking.

2. The decline in milk yield from the third to the ninth month is best considered a straight line relationship.

Literature Cited

Brody, S., A. C. Ragsdale and C. W. Turner. 1923. The Effect of Gestation on the Rate of Decline of Milk Secretion with the Advance of the Period of Lactation. Jour. Gen. Physiol. 5: 777–782.

Clapp, Howard. 1937. A Factor in Breeding Efficiency of Dairy Cattle. Amer. Soc. An. Prod., Proc., pp. 259–265.

Copeland, Lynn. 1934. Milk and Butterfat Yields of Jersey Cows as Affected by Frequency of Milking. Jour. Dairy Sci. 18: 815–821.

Edwards, J. 1936. Effect of Breed, Size of Cow, Yield of Milk, and Stage of Lactation, Upon Efficiency of Milk Production. Jour. Dairy Res. 7: 218.

Gaines, W. L. 1927. Persistency of Lactation in Dairy Cows. Ill. Agr. Exp. Sta. Bull. 288.

Gaines, W. L. and F. A. Davidson. 1926. The Effect of Advance in Lactation and Gestation on Mammary Activity. Jour. Gen. Physiol. 9: 325–332.

Gaines, W. L. and F. A. Davidson. 1926a. Rate of Milk Secretion as Affected by Advance in Lactation and Gestation. Ill. Agr. Exp. Sta. Bull. 272.

Gaines, W. L. and F. A. Davidson. 1927. Milk Yield in Relation to Recurrence of Conception. Jour. Dairy Sci. 10: 117–125.

Goulden, C. H. 1939. Methods of Statistical Analysis. John Wiley and Sons. New York, N. Y.

Hanson, W. J. and N. R. Joshi. 1934. The Persistency of Lactation as Affected by the Frequency of Milking. 10th World's Dairy Congress, Rome. Sec. IV, p. 85.

Johansson, I. and A. Hansson. 1940. Causes of Variation in Milk and Butterfat Yield of Dairy Cows. Jour. of the Royal Swedish Acad. of Agr. 79: 65–84.

Norton, H. W., Jr. 1932. Adjusting Records for Comparison. Holstein-Friesian World, 29: 799–800.

Rice, V. A. 1934. Breeding and Improving Farm Animals. McGraw-Hill, New York, N. Y.

Woodward, T. E. 1931. The Production of Dairy Cows as Affected by Frequency and Regularity of Milking and Feeding. U.S.D.A. Cir. 180.

A STUDY OF ESTRUS AND OVULATION IN THE MARE[1]

JOHN N. CUMMINGS[2]
Montana Agricultural Experiment Station

THE HORSE presents many breeding problems from the physiological standpoint, due principally to the extreme variation in estrus and the time of ovulation in the mare. Generally speaking, approximately 50 per cent of the mares bred under farm conditions conceive. Perhaps the most important reason for this low fertility in horses is that mares have not been culled on the same basis as have cattle, sheep, and swine, because a mare still remains useful as a work animal to the owner even though she will breed and produce a foal only occasionally or not at all. As a result there has not been a tendency to increase fertility in mares by selective breeding and variation has been allowed to increase through lack of selection. This has resulted in relatively low fertility in horses, as compared to other classes of livestock.

McKenzie and Andrews (1937, 1938), and Andrews and McKenzie (1941) have reported on a study of estrus and ovulation in the mare and have presented a detailed review of previous work in the latter reference. The purpose of this paper is to report additional data on estrus and ovulation in the mare.

Procedure

A study was made on sixteen mares at Montana State College during the winter and spring of 1940. These included 12 Percheron mares (three to eleven years old), two saddle mares (ten years old), and two Belgian mares (six years old). All mares except two of the Percherons were with foal before the study started. In these mares, 40 estrual periods were observed. Each mare was teased with a vigorous stallion every day beginning three to four days after foaling. Numerical ratings of their psychological responses to the stallion were recorded. This system of ratings was the same as used by McKenzie and Andrews (1937). It is as follows:

(+3)—Very receptive, (+2)—Moderately receptive, (+1)—Mildly receptive, (0)—Phlegmatic, the neither-nor type, (−1)—Passively resistant, (−2)—Mildly resistant, (−3)—Actively resistant, and (−4)—Very actively resistant.

The ovaries of each mare were palpated per rectum daily while she was in estrus until the corpus luteum formed in order to follow the development of the follicle and to determine the time of ovulation. All mares were bred

[1] Paper No. 167, Journal Series, Agricultural Experiment Station, Montana State College, Bozeman, Mont.

[2] The author is indebted to Dr. F. F. McKenzie of the Utah State Agricultural College for his advice and assistance.

as close to the time of ovulation as possible but poor results in settling them were obtained at first. This was probably due to the fact that for a long period of time the stallion used was producing sperm of very low vitality. Later successful impregnations were obtained in all except two of the Percheron mares when using the above procedure.

Results

In this study the five types of estrus which were described by McKenzie and Andrews (1938) and Andrews and McKenzie (1941) were observed. They were as follows:

(1) *Regular estrus*—Of the forty estrual periods observed, 21 were of this type.

(2) *Estrus with post estrual ovulation*—Six estrual periods of this type were observed.

(3) *Split estrus*—Four of the periods were of this type.

(4) *Physiological or silent estrus*—Three cases of this type were observed.

(5) *Estrus without ovulation*—Six cases of this type were observed. While observing two of these periods on the same mare, a follicle developed each time; but, instead of rupturing, it developed into what was later diagnosed as a cyst. However, in the other four cases no follicular development could be determined.

Additional data are presented in table 1. As mentioned above, fourteen of these mares were with foal before the beginning of the study and it was possible therefore to observe their foaling estrual periods. The number of days following foaling before the mares first showed signs of estrus ranged from 4 to 36 days with an average of 11.31 days and a standard deviation of 8.17 days in thirteen cases. One mare never showed any psychological signs of estrus during the study and while she was suckling her foal. The length of foaling estrus ranged from 0 to 10 days in length with an average of 5.71 days and a standard deviation of 3.27 days as compared with a range of 0 to 9 days with an average of 5.0 days and a standard deviation of 2.14 days for the length of the regular estrual periods (not including foaling estrus). In this study there was apparently more variation in the length of the foaling estrual period. The number of days that elapsed between foaling and the time ovulation first occurred following foaling ranged from 10 to 49 days (average, 17.8 days; S.D., 10.23 days). During the foaling estrus of one mare, ovulation did not occur as was determined by the lack of the complete development of a follicle on either ovary for that period. Two other mares showed physiological or silent estrus for that period. During foaling estrus on the other mares, ovulation occurred between 2 and 9 days after the onset of estrus (average, 5.64 days; S.D., 2.26 days). During regular estrus, ovula-

TABLE 1.—DATA ON ESTRUS AND OVULATION IN SIXTEEN MARES AT MONTANA STATE COLLEGE DURING THE WINTER AND SPRING OF 1940

Item studied		Days from foaling to first signs of estrus	Duration of estrus (days)	Days from foaling to first ovulation	Days from first signs of estrus to ovulation during same estrual period	Duration of diestrus (days)	Length of estrual cycle (days)
Foaling estrus	No.	13	14	14	11	7[3]	7[3]
	Range	4–36	0–10	10–49	2– 9	8–28	14–30
	Avg.	11.31	5.71	17.80	5.64	14.71	21.42
	S.D.[1]	8.17	3.27	10.23	2.26	6.75	5.39
	C.V.[2]	72.24	57.27	57.47	40.07	45.89	25.15
Regular estrus (not including foaling estrus)	No.		26		20	17	15
	Range		0– 9		0– 7	9–22	12–27
	Avg.		5.00		4.15	15.94	20.73
	S.D.[1]		2.14		1.54	3.90	4.46
	C.V.[2]		42.80		37.11	24.47	21.51
All estrual periods	No.		40		31	24	22
	Range		0–10		0– 9	8–28	12–30
	Avg.		5.25		4.68	15.58	20.95
	S.D.[1]		2.57		1.92	4.77	4.66
	C.V.[2]		48.95		41.03	30.62	22.24

[1] Standard deviation

[2] Coefficient of variation.

[3] These figures refer to the diestrual period following foaling estrus and to the first estrual cycle following foaling.

tion occurred between 0 and 7 days after the onset of estrus (average, 4.15 days; S.D., 1.54 days). The length of the first diestrual period following foaling estrus ranged from 8 to 28 days in length (average, 14.71 days; S.D., 6.75 days). The length of this period following regular estrus ranged from 9 to 22 days in length (average 15.94 days; S.D., 3.90 days). It is noted that there was more variation in this phenomenon following foaling estrus than that following regular estrus. The length of the first estrual cycle following foaling ranged from 14 to 30 days in length (average, 21.43 days; S.D., 5.39 days). The length of the estrual cycle other than the first one following foaling ranged from 12 to 27 days in length (average, 20.73 days; S.D., 4.46 days).

In all estrual periods studied, it was found that they ranged from 0 to 10 days in length (average, 5.25 days; S.D., 2.57 days); ovulation occurred between 0 and 9 days after the onset of estrus (average, 4.68 days; S.D., 1.92 days); the diestrual period ranged from 8 to 28 days in length (average 15.58 days; S.D., 4.77 days); and the range in the length of the estrus cycle was

12 to 30 days (average, 20.95 days; S.D., 4.66 days). In the cases where it was possible to observe more than one ovulation in the same mare, the length of time that elapsed between ovulations ranged from 12 to 29 days (average, 22.4 days; S.D., 4.46 days). The least variation occurred in the length of the estrual cycle and in the length of time between ovulations.

In order to determine the relative variation between each phenomenon studied, the coefficient of variation was calculated for each. These coefficients are presented in table 1, and it can be observed that they are all quite large, indicating a large amount of variation in all respects. However, there appears to have been relatively more variation in some phases of the study than in others, since the coefficients ranged from 20.7 to 72.2 per cent. The items compared are listed below in order of their relative degree of variation: (1) Number of days following foaling before the mares first showed signs of estrus, (2) The number of days following foaling before ovulation first occurred, (3) The length of the foaling estrual period, (4) The length of all estrual periods, (5) The number of days that elapsed between the time the mares first showed signs of estrus and the time ovulation occurred during that particular period ,(6) The length of the diestrual period, (7) The length of the estrual cycle, and (8) The length of the time that elapsed between ovulations in the same mare.

Even though considerable variations existed in estrus and ovulation in all mares studied, it is interesting to know whether each mare tended to follow somewhat the same pattern in these phenomena from cycle to cycle. From general observation it was quite obvious that there was little similarity in estrus and ovulation between mares. Also there was very little similarity between periods followed on the same mare. An analysis of variance was made on each of the following phases of estrus and ovulation: (1) length of the estrual period, (2) length of the estrual cycle, (3) length of time between ovulations on the same mare, and (4) the number of days that elapsed between the first signs of estrus and the time ovulation occurred during that period.

Significant differences were found between mares in the length of the estrual cycles ($F = 4.56$) and in the length of time that elapsed between the first signs of estrus and ovulation for that period ($F = 6.32$). However, from the analysis it was found that the variation within mares was practically the same as the total variation in the other two respects. For all practical purposes, therefore, what occurred during one period or cycle on each mare had practically no predictive value for the following periods or cycles in most cases.

Conclusions

The length of estrus and diestrus, the time of ovulation, or the type of estrus had little predictive value in the succeeding cycles from the observation of a single cycle due to the variation in the different phases of the estrual cycle studied. In most cases this fact was found true either among the cycles of the same mare or different mares. However, less variation existed in the length of the estrual cycle itself and the time between ovulations.

More variation was shown in all phases of foaling estrus than appeared in subsequent estrual periods.

Literature Cited

Andrews, F. N. and F. F. McKenzie. 1941. Estrus and Ovulation and Related Phenomena in the Mare. Mo. Agric. Exp. Sta., Research Bull. 329, 114 pps.

McKenzie, F. F. and F. N. Andrews. 1937. Estrus and Ovulation in the Mare. Am. Soc. An Prod., Proc., pp. 64–70.

McKenzie, F. F. and F. N. Andrews. 1938. Variations in Estrus and Ovulation in the Mare and Breeding Results. Am. Soc. An. Prod., Proc., pp. 228–232.

DILUTORS FOR STALLION AND JACK SEMEN[1]

V. R. Berliner
Mississippi State College

THE increased use of artificial insemination in farm animals has been closely associated with the invention of dilution media that improve the keeping qualities of semen. In Russia, undiluted semen of bulls and rams was successfully used on the centralized collective and state farms, but difficulties were encountered as soon as it became necessary to transport semen to outlying units. In this country practically all artificial insemination associations face the problem that semen has to be transported and rarely can be used immediately after it is collected.

Owing to a lack of entirely adequate dilutors, the spreading of this breeding system was rather slow because the breeding results were not good enough to induce a large scale participation. The discovery of Phillips and his associates (Phillips, 1939; Lardy and Phillips, 1939; Phillips and Lardy, 1940) that the addition of egg yolk to a suitable buffer mixture increased considerably the fertilizing and keeping qualities of semen of most domestic animals, contributed materially to a rapid increase in the popularity and widespread utilization of artificial insemination of dairy cows.

The problem of life-preserving dilutors is even more important for jack and stallion semen, for such semen is lacking in resistance, is particularly short-lived, and meets very unfavorable conditions in the female tract. These problems were reviewed and discussed in recent publications (Berliner, 1940, 1941).

Milovanov (1934, 1936) suggested several dilutors for all species of farm animals that were made up according to the physiological and chemical specificity of the different semen types.

For stallion semen dilutors, the main problem was to introduce (1) an agent that would induce anabiosis, because in undiluted stallion semen, anabiosis does not set in spontaneously; (2) an agent to supplement the low glucose content of this semen; and (3) a substance that would strengthen the weak protective sperm capsule typical of this species. These aims Milovanov achieved in stallion semen dilutors by combining glucose to serve as the additional source of energy, with an anabiotic agent: in one series of dilutors, SGL, this was sodium sulphate, and in a second series, TGL, sodium-potassium tartrate (Rochelle Salt). Peptone in small amounts was added in both series to provide a means to strengthen the protective capsule. In a later modification of the tartrate dilutor, tartaric acid and tannic acid were added

[1] Contribution from the Department of Animal Husbandry, Mississippi Agricultural Experiment Station, State College, Mississippi. Published with the approval of the Director, paper No. 57, New Series.

in small amounts to hasten the onset of anabiosis. With this dilutor, called TGL-5, Milovanov reported notably good storage results up to 5 days, especially if the seminal fluid was removed by centrifuging, and was replaced by dilutor. This replacement procedure was later used by Walton (1938) with both types of dilutors, and by McKenzie, Lasley and Phillips (1939) with the glucose sulphate dilutor. Both groups of workers obtained pregnancies with semen that was stored and even transported for 24 and 20 hours, respectively.

In breeding operations at the Mississippi Experiment Station (Berliner *et al.*, 1938, 1939, 1940, 1941), chiefly the tartrate series was used, because in comparison with the sulphate dilutors it gave consistently better results, both in fresh and stored semen. The inferior quality of sulphate-containing dilutors was obvious also in storage tests with bull semen, whereas favorable results were always obtained with a bull semen dilutor containing tartrate (TGK of Milovanov, 1936). This can be explained on the basis of observations of Torres (1935) that tartaric acid salts are present in extracts from testis tissue, and of Meyerhof and Kiessling (1935) that tartrates are intermediate products of carbohydrate metabolism (both quoted by Shergin, 1936). This could indicate that the tartrate ingredients in the dilutor are not as foreign to the metabolic processes in semen as the sulphates, and furthermore they can act as a buffer system. The high efficiency of the TGL-5 dilutor was demonstrated by the fact that in the 1940 breeding season pregnancies were obtained with semen stored with this dilutor for 24 hours. (Berliner, *et al.*, 1940).

Experimental Work and Discussion

The egg yolk buffer was used in the dilutors for jack and stallion semen during the horse breeding season of 1941. Preliminary laboratory tests were conducted with the original egg yolk and phosphate mixture as devised by Phillips (1940), and also with a mixture combining the egg yolk with the glucose-tartrate dilutors of Milovanov. This latter combination was capable of preserving the motility of a larger proportion of sperm for 100 to 150 hours than either TGL or the original egg yolk phosphate dilutor alone. No difference was found between any of the glucose-tartrate dilutors in combination with egg yolk, including a newly developed TGL-6 dilutor, for which a higher efficiency than in the older ones was claimed by Milovanov et al. (1939). The TGL-2 dilutor is simple, since it is made up of only three ingredients, as compared to five and three in TGL-5 and TGL-6 respectively, therefore the latter two were discarded and only the TGL-2 dilutor used in further work.

According to Phillips (1940), the egg yolk phosphate dilutor is made up

of equal amounts of egg yolk and buffer solution, and since in horse breeding one deals with large amounts of semen, much egg yolk was required and the preparation of such dilutor volumes was rather tedious. It was observed that the augmenting effect between TGL and egg yolk remained in force even when the volume of egg yolk was decreased to only one egg yolk for each 100 cc. of dilutor. Also, with twice this amount of dilutor per one egg yolk, no immediate damage to the sperm was observable, but the storage qualities were impaired, with fewer sperm remaining motile after 100 hours' storage. The breeding efficiency of this egg yolk-glucose tartrate dilutor was demonstrated by the fact that 13 out of 15 mares bred with fresh semen in this dilutor became pregnant. Two mares were bred with 24-hour-old semen and also became pregnant.

One obstacle to the wider utilization of semen dilutors besides their instability after their ingredients are dissolved, is the difficulty of their preparation, and the lack of methods that make them dispensable in the required amounts for a definite volume of water. This obstacle may be overcome by dispensing these amounts in gelatin capsules. The principle of using gelatin as an ingredient of dilutors was not new, since Milovanov (1937) was the first to add gelatin to ram semen dilutors. His purpose was different however, since he attempted to produce rather firm semen pellets that could be introduced into the cervix without the use of syringes and for this purpose the addition of 5 gms. of gelatin to 100 cc. water was necessary. The breeding results were satisfactory with fresh semen, but the fertilizing capacity was reduced within 6 hours' storage, even though a high degree of motility was observed after 36 hours.

Attempts to make bolets of gelatinized horse semen failed completely, since all sperm were killed during the stage of solidification of the gelatin. Therefore gelatin capsules were used principally as a means of proportioning the required ingredients for a given amount of water. This was achieved by weighing out, for 100 cc. of water, 5.76 gms. of glucose and 0.67 gms. of Rochelle salt into a ½-ounce capsule, or twice the amount for 200 cc. of water into a 1-ounce capsule. During the course of this test, we found that dissolving of the entire capsule with its contents did not impair the functions of the TGL dilutor; in fact, it appeared to add some improvements. Apparently, due to the introduction of the colloidal properties of small amounts of gelatin, the ½-ounce capsule weighing only 1.8 gms., the problem of the isotonicity between the dilutor and sperm becomes less important since no damage was done to the sperm even if the amount of TGL for 100 cc. of water was dissolved either in 75 or 125 cc. of water. The extreme limits were not determined. The storing qualities were reduced in gelatinized semen, since a considerable proportion of the sperm were dead after 48 hours of stor-

age. Breeding tests on 10 mares indicated that the fertilizing capacity of fresh semen also was slightly decreased, since only 6 mares became pregnant.

In order to combine the ease of handling of the TGL dilutor distributed in gelatin capsules with the beneficial influence of egg yolk, a method was devised by which egg yolk was added to approximately 100 cc. of gelatinized TGL dilutor. The breeding results were highly satisfactory: 16 out of 19 mares settled after being bred two and three times in one heat period with fresh semen; two more mares became pregnant after insemination first with fresh semen on their second day of heat, and again with 48-hour-old semen on the fourth day of heat. One other mare was bred only once with 48-hour-old semen and also became pregnant. Doses of ½-ounce and 1-ounce semen were given, each dose containing approximately 2 billion sperm. The rate of dilution was generally 1 part semen per 2 parts of dilutor, but occasionally, for immediate use, a dilution rate of 1:10 was necessary. The results of the observations on the different dilutors are summarized in table 1.

The preparation of dilutor capsules was further simplified by weighing out a large amount of glucose, and by adding the proportional amount of Rochelle salt. The two ingredients were thoroughly mixed, and the required amount of 6.43 grams weighed out into ½-ounce capsules. This is simpler than weighing separately the individual doses of both ingredients into each capsule, and the filled capsules can be stored in a dry place for a considerable time.

Sterilizing the dilutor is important. This can be achieved in the following way:

A wide-mouthed bottle, allowing the introduction of a ½-ounce or 1-ounce capsule, serves as a container. On the bottle is marked the level for 100 and 200 cc. Freshly boiled hot water is filled up to the desired level and a capsule with TGL is dropped into the bottle. While the capsule is dissolving, one egg yolk is prepared by separating it from the egg white, and placing it in a 50 cc. beaker. A stream of distilled or boiled water is directed into the beaker and all adhering strands of egg white washed off. The egg yolk is then removed onto a piece of filter paper, placing it close to the edge. The skin around the egg yolk is pierced with a sharp instrument and the outflowing egg yolk is directed into the dilutor bottle. The temperature of the dilutor should be kept below 80° C, so the egg yolk will not coagulate. The entire mixture is shaken up to insure even distribution of the egg yolk. The bottle is then kept in a water bath at 60° to 70° C for ½ hour. Since this is the temperature for milk pasteurization, destruction of harmful bacteria is achieved. Culture tests on bacteriological culture media were negative.

The gelatinized dilutor solidifies into a jelly-like consistency at a temperature of 10° to 15° C, and has to be re-heated to 25° to 30° after it has been

TABLE 1.—COMPOSITION OF DILUTORS AND THEIR EFFECT ON THE LONGEVITY OF SPERM OF JACKS AND STALLIONS, AND ON THE BREEDING RESULTS

Formula and items compared	Dilutor						
	TGL-2	TGL-5	TGL-6	TGL+ gelatin	TGL+ egg yolk	TGL+ egg yolk+ gelatin	Egg yolk + phos.
Formula of dilutor, in grams per 100 c.c. water:							
Glucose	5.76	6.48	6.85	5.76	5.76	5.76	
K-Na tart.	.67	.33	.15	.67	.67	.67	(2.0 gms.
Tart. acid	—	.01	.008	—	—	—	Na_2HPO_4
Tannin	—	.002	—	—	—	—	+0.2 gms.
Peptone	.2	.8	—	—	—	—	KH_2PO_4)
Egg yolk	—	—	—	—	30	30	100
Gelatin, as capsules	—	—	—	1.8	—	1.8	—
No. of samples studied	20	30	6	20	30	30	5
Percent of sperm active at							
48 hours	70	90	70	60	90	90	80
100 hours	50	60	30	40	70	80	60
No. of animals inseminated	32	36	—	10	17	22	—
Percent pregnancies obtained	78	81	—	60	88	86	—
Remarks	Suitable for immediate use	Suitable for 24 hrs. storage	Not suitable for storage	Not suitable storage but regulates tonicity	Suitable for immediate use and 24 hrs. storage	Easy to prepare, avoids shock, very good for storage	Suitable for storage

stored in the refrigerator. Thus a temperature shock by adding too cold stored dilutor to freshly collected semen is eliminated by necessity. This is perhaps a superfluous safety measure because it seemed that gelatinized semen is less susceptible to temperature shock. Lasley, et al. (1941) found that bull semen loses its sensitivity to temperature shock in the presence of egg yolk dilutor.

In diluted semen congealing is almost complete within 30 to 40 minutes, at 5° to 10° C, if semen is kept at a refrigerator temperature of 2° to 5° C. Within one hour, a temperature of 8° C is obtained, with a cooling rate that

is well within the limits of a 1° drop for each 2 minutes' cooling, as suggested by McKenzie, Lasley, and Phillips (1940). The more gradual cooling as found necessary in our previous work with the old TGL-5 dilutor did not have a beneficial effect, but rather the opposite, because apparently with the gradual onset of low temperatures congealing took place at a more rapid rate than the suppression of the life processes in the sperm, with the result that they spent too much energy attempting to swim around in the stiffening medium, and therefore showed less motility after storage.

Summary

A dilutor for jack and stallion semen is prepared by dissolving a ½-ounce gelatin capsule containing 5.76 grams glucose and 0.67 gms. Rochelle salt in 100 cc. water and adding one egg yolk. This dilutor can be pasteurized for sterilization. It can be added to stallion and jack semen in a proportion of up to 1:10 for use shortly after collection of semen. For storage purposes a ratio of 1:3 seems more adequate. Pregnancies were obtained with semen that was stored for 24 and 48 hours.

Literature Cited

Berliner, V. R. 1940. An Improved Artificial Vagina for the Collection of Stallion and Jack Semen. Jour. Am. Vet. Assoc. 96: 667–670.

Berliner, V. R. 1941. Problems of Artificial Insemination in Horse and Mule Production. Jour. Am. Vet. Assoc. 98: 384–388.

Berliner, V. R., F. E. Cowart, R. H. Means and J. B. Wright. 1938. Artificial Insemination for Horse, Mule and Jack Stock Production. Am. Soc. An. Prod., Proc., pp. 233–237.

Berliner, V. R., F. E. Cowart and L. L. Pharis. 1939. The Effect of Feed on Sperm Production of Jacks and Stallions and Some Physiological Properties of Their Semen. Am. Soc. An. Prod., Proc., pp. 225–231.

Berliner, V. R., F. E. Cowart and L. L. Pharis. 1940. Cold Storage Colts. Jour. Heredity, 31: 449–451.

Lardy, H. A., and P. H. Phillips. 1939. Preservation of Spermatozoa. Am. Soc. An. Prod., Proc., pp. 219–221.

Lasley, J. F., G. T. Lasley and R. Bogart. 1942. Some Factors Influencing the Resistance of Bull Sperm to Unfavorable Environmental Conditions. Jour. An. Science, 1: 79.

McKenzie, F. F., J. F. Lasley and R. W. Phillips. 1939. The Storage of Horse and Swine Semen. Am. Soc. An. Prod., Proc., pp. 222–225.

Milovanov, V. K. 1934. Principles of Artificial Insemination. Gosizdat Moscow.

Milovanov, V. K. 1936. Artificial Insemination of Farm Animals. Gosizdat Moscow.

Milovanov, V. K. 1937. Insemination of Sheep with Gelatinized Semen. Probl. An. Husb. 10: 53–58.

Milovanov, V. K., A. N. Lichacev, and T. A. Zebenieva. 1939. Preservation of the Fertilizing Ability of Stallion Sperm by Artificial Anabiosis. Sov. Zootech. 4: 31. Abstr. in An. Breed. Abstr. Edinb. 8: 110.

Phillips, P. H. 1939. Preservation of Bull Semen. Jour. Biol. Chem. 130: 415.

Phillips, P. H. and H. A. Lardy. 1940. A Yolk Buffer Pabulum for the Preservation of Bull Semen. Jour. Dairy Sci. 23: 379–403.

Shergin, N. P. 1936. The Energy of Spermatozoa and the Problem of Sperm Preservation. Probl. An. Husb. 9: 124–149.

Walton, A. 1938. Preservation of Fertilizing Capacity of Horse Semen. Am. Soc. An. Prod., Proc., pp. 238–241.

VITAMIN B_6 (PYRIDOXINE) IN THE NUTRITION OF THE PIG

E. H. Hughes and R. L. Squibb[1]
University of California[2]

Introduction

Chick (1938) as early as 1938, showed that pigs deprived of an eluate fraction developed what they termed epileptic fits and a microcytic anemia. This eluate fraction contained vitamin B_6. When the eluate fraction was provided the blood returned to normal and the fits ceased.

Convulsions were reported by Wintrobe (1939) among pigs fed a highly purified diet when deprived of yeast.

One of the authors (1938) suspected the necessity of vitamin B_6 in the nutrition of the pig because a rice bran filtrate, when added to a diet deficient in pantothenic acid and vitamin B_6, resulted in increased gains and physical well-being. The rice bran filtrate contained pantothenic acid and some vitamin B_6.

Experimental

Three experiments were conducted in this series: the first, during the summer of 1940; the second, in the winter of 1940–41; and the third, during the winter of 1941–42. Altogether, 24 pigs were used in these studies, 12 were fed diets deficient in vitamin B_6, and 12 were fed rations containing 5 mg. of vitamin B_6 (pyridoxine) per 100 pounds of pig daily. The pigs were uniform in age, size, type and thrift when placed on experiment. The average beginning weight was slightly more than 30 pounds each. They had access to inside and outside pens of uniform size, with concrete floors. They were fed and watered in steel troughs. Weekly rations were mixed in a metal feed box and stored in separate paper-lined metal cans. The vitamins were carefully weighed, placed in water solution, then mixed with casein which was incorporated into the diet with the other components. The pigs were fed twice daily and were weighed each week.

The basal ration was composed of: sugar (beet) 81%; purified casein 5%, salt mixture 4%; and each animal was given 10 cc. of cod liver oil weekly. The vitamins were given in the following amounts, per 100 pounds of pig daily: thiamin 3 mg.; riboflavin 4.5 mg.; pantothenic acid 10 mg.; and nico-

[1] The authors express their gratitude to Mrs. Lillian Lagemann for making the blood cell counts, smears, and some of the hemoglobin determinations; to Dr. F. R. Smith, who made the yeast and mold population studies; and, to Lt. N. R. Ittner, who helped with the first 2 experiments and who aided in organizing the last experiment before joining the armed forces.

[2] Division of Animal Husbandry, College of Agriculture, Davis, California.

tinic acid 15 mg. In the control ration, 5 mg. of vitamin B_6 (pyridoxine hydrochloride) was provided per 100 pounds of pig daily.

The salt mixture, in percentage, was made up of the following constituents: calcium phosphate (dibasic) 40; sodium chloride 20: calcium carbonate 11; potassium chloride 10; ferric chloride 3; magnesium citrate 15; cobaltous acetate 0.1; copper sulphate 0.2; manganese sulphate (anhydrous) 0.5; zinc oxide 0.1; and potassium iodide 0.1.

Hemoglobin determinations were made on the blood of the deficient and control pigs. Blood counts of the red corpuscles and leucocytes were taken in a few cases.

Results

In the first two experiments there was no difference in the food consumption, the growth rate, the physical well-being and in the percentage hemoglobin in the blood of the pigs fed diets deficient in vitamin B_6 and of the controls. In the deficient groups there was no evidence of epileptic-like fits, or of anemia as described by Chick and co-workers (1938). Because other species need this factor, it seemed logical to assume that the pig also needed it. The animals were watched carefully during all parts of the day. It was finally noticed that those on the deficient diet licked the floors of their pen and the floor of the runway to the scale when being weighed. A check of pen floors showed a large flora of yeasts and molds. Part of the diet was spilled on the floor which, together with moisture and proper temperatures, resulted in the growth of these organisms. It was postulated that probably vitamin B_6 was being synthesized on the floor and that the pigs were able to ingest enough to satisfy their needs.

Prior to the last experiment, the floors of the pens were thoroughly cleaned and a fine sand and cement wash was applied in an effort to make it smooth.

Before the experiment began, the floors were thoroughly washed with a wetting powder and also a strong lye solution. This was repeated 3 times each week throughout the experiment. The floors were checked at stated intervals for yeasts and molds and they were found to be materially lower than those of untreated floors. This was accomplished by placing a Ball Mason jar ring on the floor. Melted Sabouraud's was poured into this ring to a depth of approximately 3 mm. It was allowed to harden, picked up with a spatula and placed in a sterile petri plate. The portion of agar which had been in contact with the floor was esposed to the air in the dish. Plates were incubated at 30° C and examined after 48 and 72 hours, respectively.

The experiment began early in December, 1941. Late in the same month, the deficient group were unsteady on their legs, off feed and their hair ap-

peared rougher than that of the controls. By January 16, 1942, the deficient pigs were scouring, their appetites were poor and their rate of growth was not equal to that of the controls. Scouring had increased 4 days later, and one of the pigs had a spasm, which consisted of squealing for about 20 seconds, followed by the animal doubling up and shaking all over. This fit lasted for about 4 minutes.

In the meantime, the pigs had ceased to gain (see figure 1), their appetites

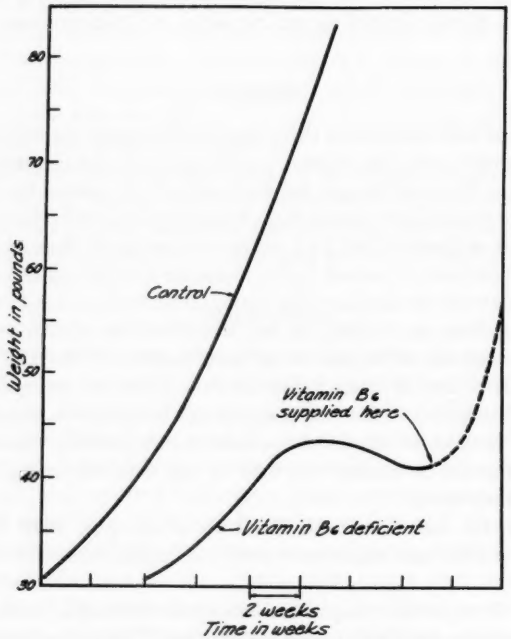

Figure 1. Growth curves of deficient and of control pigs.

being very poor. By February 3rd, the whole group were very unthrifty, and by February 15th, all of the deficient pigs had fits. Some had many, others had only a few. They would last from 2 up to about 10 minutes. At first, the pigs would have an occasional fit; later, they became more and more frequent.

A typical epileptic-like fit might be described as follows: A pig would be walking about the pen when suddenly he would stop, become unsteady on his feet and fall on his side, struggling violently, and screaming with a high-

pitched voice (see figure 2), with mouth open and legs kicking out in all directions, then his body would stiffen with head back and with open starry eyes. This would be followed by a comatose stage when the pig appeared dead. Respiration was first deep, then shallow, then deep again. In about a minute or two, the pig would regain partial consciousness, would arise and stagger in any direction. Finally, in a few seconds, he would become conscious and would walk to the trough and drink water and would appear normal though somewhat weakened.

Figure 2. Active stage of the "vitamin B_6 deficient fit."

Hemoglobin determinations were made, using the Sahli method. The average of 2 control pigs, taken January 20th, was 73.5 per cent. The average for 3 of the deficient pigs, taken the same time, was 46.7 per cent, and by February 15th, the average of all the deficient pigs was 39.6 per cent. The highest was 43 and the lowest 36. The average of 3 control pigs was 80.3 per cent. The temperatures and respiratory rates were secured February 18th, and they were normal.

On February 15th, blood samples were taken from 2 deficient and from 2 control pigs. The average red and white cell count for the controls was 7,600,000 and 23,400, respectively; and for the deficient pigs it was 5,000,000

and 12,400. Blood smears were taken at the same time and by comparison the red cells from deficient animals were about 60 per cent as large as those of the blood of normal pigs. There were a large number of normablasts. From these results the deficient animals apparently showed a microcytic hypochromic type of anemia similar to that reported by Chick and coworkers (1938).

On February 21st, each of three deficient pigs were given 15 mg. of vitamin B_6 orally, and from that time until the experiment closed they were given pyridoxine at the rate of 5 mg. per 100 pounds of pig daily. In less than a week they ceased having fits, and on March 11, the average percentage hemoglobin was 73.6, which was normal for pigs of that age and weight.

Before prophylactic measures were instituted, the pigs were in poor shape, their hair was dry, their appetites were very poor, there was some loss of hair, and their gaits were not normal. Toward the end of the experiment, some of the pigs acted somewhat like pantothenic acid deficient pigs, which would indicate that because of a very low intake of food, a multiple deficiency was manifesting itself.

The 3 deficient pigs fed vitamin B_6 showed an improved appetite in less than a week, and by the end of the experiment (March 11th) their appetites were excellent, which was reflected in their gain in weight. (See figure 1.)

Of the 2 pigs remaining on the vitamin B_6 deficient diet, one died February 27th, and the other was killed and autopsied on March 4th. Nothing specific was found at autopsy, except in one case the kidneys were very light colored and the walls of the bladder were thickened; while in the other, there were a number of ulcers in the large intestine. Otherwise, the organs appeared normal.

Discussion and Summary

In these studies, because of faulty technique, we failed in the first 2 experiments to demonstrate that vitamin B_6 was necessary for the young pig. In the last experiment, however, when the floors were kept practically free of molds and yeasts, it was shown that the young pig needs this nutritional factor. The deficient symptoms were similar to those described by Chick (1938) of pigs fed a diet deficient in the eluate factor used by them. It seems certain that the vitamin B_6 in the eluate factor was responsible for their results.

It appears that a lowered food intake toward the end of the experiment resulted in some symptoms of a pantothenic acid deficiency in certain of the vitamin B_6 deficient individuals. There were no such symptoms in the control group, even though the only difference in the diets was the inclusion of pyridoxine in their feed.

That vitamin B_6 is necessary in the diet of the pig has been demonstrated. A deficiency of this factor resulted in poor appetites, reduced growth, unsteady gaits, epileptic-like fits and convulsions, and a microcytic hypochromatic anemia. Providing this factor in the diet, resulted in a cessation of the fits, a return to normal blood hemoglobin and a resumption of growth and physical well-being.

The control pigs were fed the same diet as the deficient pigs, except that they received 5 mg. of synthetic pyridoxine per 100 pounds of pig daily. Inasmuch as these pigs made normal gains and showed none of the symptoms of the deficient pigs, it appears that under the conditions of this experiment the minimum requirement of pyridoxine hydrochloride for pigs of this size and age lies somewhere between 0 and 5 mg. per 100 pounds of pig daily.

Literature Cited

Chick, Harriette, Thomas Fotheringham Macrae, Archer John Porter Martin, and Charles James Martin. 1938. The Water-soluble B-Vitamins, other than Aneurin (Vitamin B_1), Riboflavin and Nicotinic Acid Required by the Pig. Biochem. Jour. 32: 2207–2224.

Hughes, E. H. 1938. The Vitamin B Complex as Related to Growth and Metabolism in the Pig. Hilgardia, 7: 595–612.

Wintrobe, M. M. 1939. Nutritive Requirements of Young Pigs. Amer. Jour. of Physiology. 126: 375–387.

EXPERIMENTAL DESIGN FOR TESTING INBRED LINES OF SWINE[1]

G. E. Dickerson[2]
U. S. Department of Agriculture

IN THE process of developing and utilizing inbred lines of farm animals, comparisons of these lines must be made to determine which are most useful. The size of the differences expected between lines, and the number of animals necessary for statistical significance, are variously affected by such things as: (1) the kind of comparison (i.e. whether between the inbred lines, between linecrosses, between topcrosses, etc.); (2) the homozygosity of the inbred lines; (3) relationship between the inbred lines; (4) the degree of heritability of the characters concerned; (5) the experimental plan followed; and (6) prior selection, particularly culling of lines. The present paper indicates how the design of an experiment will be modified by some of these factors.

General Form of Analysis

The analysis will take the form shown in table 1, when the groups are compared within a single season and treatment, provided each group is from a different set of parents. The appropriate test of significance for group differences is:

$$(1) \qquad F = \frac{A+nB+ndC+ndsD}{A+nB+ndC} = 1+\frac{ndsD}{A+nB+ndC}$$

with degrees of freedom of $(g-1)$ between groups and $g(s-1)$ for the error mean square.

When a comparison of the same groups is repeated with different sires and dams in a number (y) of different seasons and in several (k) different herds each season, it seems likely that differences between herds and between seasons will affect different groups in nearly the same proportion. If such is the case, the degrees of freedom available for estimating the error mean square include those for the various interactions of groups with herds and with seasons, as well as those between sires within the group replications. The test of significance is:

$$(2) \qquad F = 1+\frac{ndsykD}{A+nB+ndC}$$

[1] Journal Paper No. J-1013 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 32.

[2] The author wishes to express his appreciation to Dr. J. L. Lush of the Iowa Experiment Station for many helpful suggestions during the preparation of this manuscript. The author is associate geneticist, Regional Swine Breeding Laboratory, Bureau of Animal Industry, Ames, Iowa.

TABLE 1.—ANALYSIS OF DATA FROM A SINGLE SEASON AND TREATMENT[1]

Source of variation	Degrees of freedom	Composition of mean square[2]
Between groups compared	$g-1$	$A+nB+ndC+ndsD$
Between sires within groups	$g(s-1)$	$A+nB+ndC$
Between litters within sires	$gs(d-1)$	$A+nB$
Between litter mates	$gsd(n-1)$	A
Total	$gsdn-1$	$A+\frac{(gsd-1)nB+(gs-1)ndC+(g-1)ndsD}{gsdn-1}$

[1] Where g = number of groups (i.e. different inbred lines, topcrosses, or linecrosses),
s = number of sire progenies per group,
d = number of litters per sire,
n = number of pigs per litter,
A = variance between litter mates,
B = extra variance between paternal half-sibs of same group,
C = extra variance between non-sibs of same group,
D = extra variance between pigs from different groups,
$A+B+C+D$ = total variance, if each pig is from a different group.

[2] Based on the extension of R. A. Fisher's suggestions in Section 40 of his "Statistical Methods for Research Workers," as used by J. L. Lush in several unpublished manuscripts, and by C. P. Winsor and G. L. Clarke (1940).

with $(ykgs-yk-g+1)$ degrees of freedom for error. Fewer degrees of freedom are available for error if the same sires are used in more than one season or herd.

When D is defined as the extra variance between animals from different groups in the *whole population of groups*, the real difference between *two groups* which would produce a group variance equal to D in the whole population is $\sqrt{2D}$.[3]

Expected Differences Between Groups, Size of D

D, C, B, and A are constituted as shown in table 2 when all gene effects combine additively. In the general formulae of table 2, f is Wright's (1921) average inbreeding coefficient for the animals in the particular kind of groups being compared, f' is the inbreeding of their dams, and the V's are the vari-

[3] For a difference between two groups, the standard error is $\sqrt{\frac{2(A+nB+ndC)}{ndsyk}}$, and

$$t=\sqrt{F}=\frac{\text{Difference}\sqrt{ndsyk}}{\sqrt{2(A+nB+ndC)}}=\sqrt{\frac{A+nB+ndC+ndsykD}{A+nB+ndC}}$$

Hence, the average difference is $\sqrt{\frac{2(A+nB+ndC+ndsykD)}{ndsyk}}$, of which only $\sqrt{2D}$ represents a real difference between the groups. $\sqrt{2D}$ is larger than the mean real difference (disregarding sign) between *any* two groups in a normally distributed population of group means. The latter is only about $.8\sqrt{2D}$, since for n differences which vary in size the mean of the squared differences is larger than the square of the mean difference.

ances from the different sources for an outbred population comparable to that from which the inbred lines were developed:

V_g = Variance due to the genes of the pigs themselves;
V_m = Environmental variance between litters due to genetic differences in mothering ability of dams;
V_d = Variance due to other environment common to litter mates;
V_e = Variance due to random environmental differences between litter mates.

Cov, Cov_p, Cov_s, and Cov_d are the covariances which are the numerators of Wright's (1921) relationship coefficient between animals of the same group which are non-sibs, paternal half-sibs, full-sibs, and dams, respectively.

TABLE 2.—COMPOSITION OF VARIANCE IN AN UNSELECTED POPULATION OF UNRELATED GROUPS

Component of variance	Expected size
Between groups = D	$Cov\ V_g + Cov_d\ V_m$
Between sires within groups = C	$(Cov_p - Cov)V_g$
Between litters within sires = B	$(Cov_s - Cov_p)\ V_g + (1+f' - Cov_d)\ V_m + V_d$
Between litter mates = A	$(1+f - Cov_s)\ V_g + V_e$
Total = $A+B+C+D$	$(1+f)\ V_g + (1+f')\ V_m + V_d + V_e$

The size of D expected in the different kinds of comparisons is as shown below if the lines are unrelated and if mating is random within each line. The f used in the following formulae is the average inbreeding of offspring within the lines, since the covariance between inbred parents of the same group is $2f$, regardless of the kind of comparison:

$D = 2f(V_g + V_m)$ between the inbred lines themselves;
$D = f(V_g + 2V_m)$ between linecrosses having no parent line in common;
$D = \frac{fV_g}{2}$ between topcrosses of different lines on the same outbred stock, or between linecrosses having one inbred line as the common female parent;
$D = \frac{f}{2}(V_g + 4V_m)$ between linecrosses having one line as the common male parent;
$D = \frac{f}{4} V_g$ between the topcross of an inbred line and outbred stock, provided the average merit of the whole population of topcrosses is equal to that of the outbred stock.

The part of D due to genetic differences in the offspring themselves (V_g) is expected to average only half as large between linecrosses having no parent line in common as between inbred lines; this part of D averages one-fourth as large between topcrosses as between inbred lines, and only one-eighth as large in comparisons of individual topcrosses with outbred stock as in comparisons of different inbred lines. Variance due to genetic differences in the mothering ability of dams (V_m) is equally important in D between inbred lines and between linecrosses. As the homozygosity of the lines increases, the average D expected approaches maxima of $2(V_g+V_m)$ between inbred lines, (V_g+2V_m) between linecrosses, $\frac{V_g}{2}$ between topcrosses, and $\frac{V_g}{4}$ in comparing individual topcrosses with outbred stock.

The effect of the inbreeding of the lines on the expected sizes of D, C, B, and A in populations of inbred lines, linecrosses, and topcrosses, is illustrated for weight of swine at 180 days of age in figure 1. This illustration is typical for inbred lines in which contemporary members average half-sibs in addition to any relationship through the grandparents. The total variance is expressed in terms of $A+B+C+D=1$ in the initial outbred population. The

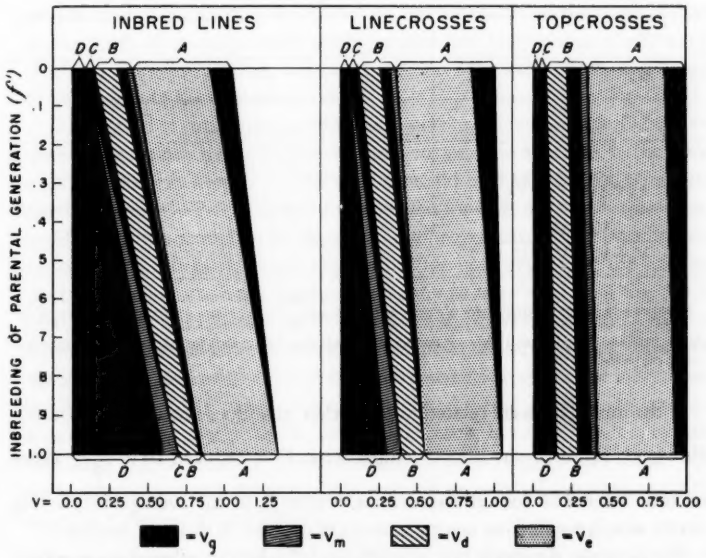

Figure 1. Effect of inbreeding on D, B, C, and A for weight at 180 days.

variances used as representative of the initial outbred stock are given in table 3. These variances are based upon unpublished analyses by J. A. Whatley, Jr., and L. N. Hazel of data from the herd of swine maintained cooperatively by the Iowa Agricultural Experiment Station and the Regional Swine Breeding Laboratory.

TABLE 3.—MEANS AND INITIAL VARIANCES FOR TWO CHARACTERISTICS OF SWINE

	Weight at 180 days of age (pounds)	Productivity index of sows[1]
Mean	180	27.4
Standard deviation	32	9.8
V_g	311.3	17.46
V_m	51.9	0
V_d	155.6	0
V_e	518.8	79.54
$\frac{V_g}{V_g+V_m+V_d+V_e}$	.30	.18
$\frac{V_m+V_d}{V_g+V_m+V_d+V_e}$	.20	0

[1] As used here, the productivity index of sows $= n_0+n_{21}+n_{56}+\frac{W_{21}}{10}+\frac{W_{56}}{30}$, where n refers to the number of live pigs per litter and W to the litter weights, at the indicated ages in days. Five units in the index are roughly equivalent to each pig weaned per litter.

If the inbred lines are related to each other, that does not affect A, B, or C. However, in all of the above comparisons, D is reduced to $\frac{(f-f_0)}{f}$ times what it would be for unrelated lines, where f_0 is the average inbreeding which would result from mating animals of one line to those of another.[4]

For example, if a single line was subdivided when its inbreeding averaged 15 per cent and the average relationship between the animals of one subline and those of another was 25 per cent, $f_0=\frac{.25\ (1.15)}{2}=.144$. When the in-

[4] All of the reduction in gametic variance, as compared with what would exist in a population of unrelated lines, is taken from the variance between lines. Thus, the covariance between uniting gametes within the population of related inbred lines is $(f-f_0)$ instead of f. In comparisons of related linecrosses, the appropriate value of f_0 is calculated from the average relationship of the inbred lines used in one linecross to those used in another.

breeding of the animals in the sublines has advanced to 30 per cent, the average component of variance expected between the sublines is $D = 2(.3 - .144)(V_g + V_m) = .312(V_g + V_m)$. This is only about half as large as if these lines were 30 per cent inbred but unrelated, and is about the same as between unrelated lines inbred only 15 per cent. Clearly relationship between the inbred lines should be avoided if maximum differences between lines are desired.

Selection during the course of the inbreeding and non-additive effects of genes are the only omitted factors likely to make the preceding calculations of D be much in error. Epistasis, and dominance (if dominant genes are more frequent than their recessive alleles), would cause inbreeding to increase D and reduce B and A more than is calculated from table 2. This underestimation of D becomes larger as inbreeding progresses. Heterosis would cause the average level of expression of a character to be higher for linecrosses, topcrosses, and outbreds than for the inbred lines themselves. However, if shifts in the level of the expression affect genetic and non-genetic variations in much the same proportion, such shifts should have little effect on the ratio of differences to their standard errors.

Elimination of entire lines among the poorer ones could reduce D between lines to far below that calculated. Also, continuous selection within lines could conceivably keep D smaller than it would be if no selection were practiced, particularly if the intensity of selection for each character were varied in different lines according to the need for improvement.[5] If culling of inferior animals within lines automatically selects for heterozygosity, the homozygosity of the lines will not increase as rapidly as calculated from the mating system. However, this effect will be trivial except under extremely mild inbreeding. If the initial variances are determined for outbred descendants of the foundation animals, selection of the foundation stock for the inbred lines would not affect the accuracy of the calculated size of D except in comparisons of topcrosses with commercial outbred stock. If the selection of foundation stock and of breeding animals within the lines is really very effective, it could introduce a real difference between the mean of all topcrosses and the mean for commercial outbred stock.

[5] For example, suppose the stock of one line is good in fertility but poor in growth rate, while that of another line is opposite in character. Intensive selection for growth rate within the first line with little attention to fertility, and the reverse emphasis within the second line, should decrease the difference between the lines in both respects. However, if selection within lines is based on a total score or index, each character receiving the same relative weight regardless of the line concerned, selection within lines should do little to keep them from drifting apart as inbreeding progresses, although it might change the average of the whole population of inbred lines considerably as compared with unselected outbred stock.

Factors Affecting the Standard Error of Group Differences

The standard error of a difference between two groups having no sires or dams in common is:

$$S_{\bar{d}} = \sqrt{\frac{2(A+nB+ndC)}{ndsyk}}$$

with $(gyks-g-yk+1)$ degrees of freedom.

In general, the genetic portion of A, B, and C declines as the lines become more highly inbred. Using f' to designate the inbreeding of the parents from the inbred lines and f for the inbreeding of their offspring *within the lines*, regardless of the kind of comparison, the expected size of these components of variance may be expressed as follows:

$$C = \frac{(1+f'-2f)V_g}{4}$$

within inbred lines, linecrosses, or topcrosses, since different sires of the same group are from one inbred line in all three cases.

B and A are the same within inbred lines as within linecrosses:

$$B = \frac{(1+f'-2f)(V_g+4V_m)}{4} + V_d, \text{ and } A = \frac{(1-f')V_g}{2} + V_e.$$

Within topcrosses, B and A are larger to an extent which depends on the difference in heterozygosity between outbred dams and dams from the inbred lines:

$$B = \frac{V_g}{4} + V_m + V_d, \text{ and } A = \frac{(2-f')V_g}{4} + V_e.$$

For economic characters, a large part of A, and oftentimes of B as well, is due to environmental variation, and increased inbreeding may reduce the standard error very little even when all intra-line genetic variability disappears. (See figure 1.) Hence, the effect of inbreeding in making it easier to detect differences between groups comes mostly from its effect on the size of D.

Increasing the number of sire progenies per group (s) or the number of replications (y and k), reduces the fraction of all components of variance represented in the standard error, and also provides more degrees of freedom for error. On the other hand, degrees of freedom are unaffected by the number of litters per sire (d) and the number of pigs per litter (n). Increases in d reduce only the B and A portions of the standard error, while increases in n reduce only the A portion. Thus, fewest animals are necessary for the statistical significance of a group difference if no two animals within a group have the same sire; i.e. if the n and d are each only one. However, in experiments

with swine the overhead cost of weaning a litter is nearly the same whether the sow raises one or ten pigs, and A represents more than half of the intra-group variance among individual pigs for important swine characters. Hence, unless the cost of making the observation is high, it may often be advisable to observe at least 4 or 5 pigs per litter so as to reduce the A portion of $S_{\bar{d}}$ substantially. When n is as much as 5, the fraction of A in $S_{\bar{d}}$ has already been made relatively small (i.e. $\frac{A}{5}$). While an increase in the number of litters per sire (d) will reduce the fraction of A in $S_{\bar{d}}$ a little further, its main usefulness is only to reduce the fraction of B in $S_{\bar{d}}$. The saving in the smaller total numbers of litters necessary for statistical significance when more boars are used must be weighed against the increased cost for boar service. For 180-day weight of swine, almost no further reduction in the number of sire progenies (s) required for the significance of group differences is accomplished by increasing the litters per sire (d) beyond 3, or at most 4. Of course, for swine characters like the productivity of sows which can be observed on only part of the litter, or in experiments with animals like sheep or cattle which have little more than one offspring per dam each year, there is more advantage in increasing the number of dams per sire (d).

The total number of sire progenies (yks) required to provide a given number of degrees of freedom for the error mean square is very little larger when the data are obtained from y different seasons and k different farms than when all data are from a single season and one farm. However, the numbers of animals per group (nds) should be kept nearly the same for each of the groups compared in any one herd-season replication, if standard errors are to be kept at a minimum and troublesome corrections for disproportionate sub class numbers are to be avoided in analyzing the data obtained.

Requirements for Significant Group Differences in Weight and Productivity

The average numbers of replications (yk) required to expect statistically significant differences in 180-day weight and productivity between two unrelated inbred lines are given in table 4 for different degrees of inbreeding of the lines, and for varying numbers of sires per line (s) and litters per sire (d) in each replication. To conserve space, the numbers required for significant differences between two groups in the other kinds of comparisons, which are considered separately, will be expressed approximately as multiples of the numbers given in table 4. The numbers in table 4 were calculated from formula (2) and table 2, using the initial variances found in table 3 and assuming that contemporary members of a line average half-sibs in addition to

TABLE 4.—NUMBERS OF REPLICATIONS of (sk) REQUIRED TO DETECT SIGNIFICANT DIFFERENCES IN 180-DAY WEIGHT BETWEEN TWO UNRELATED INBRED LINES
(Numbers in parentheses are for the productivity index of sows)

Sires per line (s)	Litters per sire (d)	Inbreeding of parents (f')[1]						
		.0	.1	.2	.3	.4	.5	1.0
1	2	11 (21)	8 (14)	6 (11)	5 (9)	5 (8)	5 (7)	3 (5)
	3	9 (16)	7 (11)	6 (8)	5 (7)	4 (6)	4 (6)	3 (4)
	4	8 (13)	6 (9)	5 (7)	5 (6)	4 (6)	4 (5)	3 (4)
	5	8 (12)	6 (8)	5 (7)	4 (6)	4 (5)	4 (5)	3 (4)
2	2	5 (10)	4 (7)	3 (5)	3 (4)	2 (4)	2 (3)	2 (2)
	3	4 (8)	3 (5)	3 (4)	2 (3)	2 (3)	2 (3)	1 (2)
	4	4 (6)	3 (4)	2 (3)	2 (3)	2 (3)	2 (2)	1 (2)
3	2	4 (7)	3 (5)	2 (3)	2 (3)	2 (3)	2 (2)	1 (2)
	3	3 (5)	2 (4)	2 (3)	2 (2)	1 (2)	1 (2)	1 (2)
	4	3 (4)	2 (3)	2 (2)	1 (2)	1 (2)	1 (2)	1 (2)
4	1	4 (9)	3 (6)	2 (4)	2 (3)	2 (3)	2 (3)	1 (2)
	2	3 (5)	2 (4)	2 (3)	1 (2)	1 (2)	1 (2)	1 (1)
	3	2 (4)	2 (3)	1 (2)	1 (2)	1 (2)	1 (2)	
Expected line difference, $\sqrt{2D}$	180-day weight (lbs.)	13.5	17.3	20.7	23.5	26.1	28.4	38.1
	Productivity index[2]	2.95	3.80	4.53	5.16	5.72	6.23	8.36

[1] If the inbred lines compared are related, average differences expected and numbers required are roughly those for $f'-f_0$. See footnote 4, page 330.

[2] See footnote 1, table 3, for the unit of the productivity index.

any relationship through their grandparents. The number of pigs per litter (n) used in the calculations was 6 for 180-day weight and 2 for the productivity index of sows. The conventional 5 per cent level of significance was used. Numbers required for the 10 per cent level of significance are only a little smaller than shown in table 4, but are about half-again as large for the 1 per cent level.

Non-additive gene effects would tend to make the average variation between groups larger than calculated. This discrepancy will become larger as inbreeding becomes higher. For this reason, the estimates in table 4 of numbers required may be somewhat too large, particularly for the higher levels of inbreeding. On the other hand, prior culling of some of the inferior lines and effects of selection within lines (if emphasis within each line was directed most at that line's most serious weaknesses) might reduce differences

between groups, making these estimates of numbers low. The general applicability of these estimated requirements also depends on how truly the Iowa data given in table 3 represent the general heritability of weight for age and of productivity of sows.

If more than two groups are included in each replication, the standard error of a difference between two groups is no smaller, but more degrees of freedom are available for estimating its size and fewer seasons of replication than stated in table 4 will be necessary. For example, if five groups are included in each season of replication, the numbers of seasons required are smaller than given in table 4 by one-third to one-half. Also, when more groups are included in each replication, group heterogeneity in the whole population of groups is more likely to be significant.

Comparisons of Inbred Lines

As shown in table 4, expected differences between inbred lines ($\sqrt{2D}$) are rather large even at moderate inbreeding levels. For example, $\sqrt{2D}$ reaches 10 per cent of the mean weight at 180 days—18 pounds—when parental inbreeding (f') is little more than 10 per cent. For the productivity index of sows, 10 per cent differences—equivalent to a little more than half a pig per litter—are expected before the parents within each line average as closely related as half-sibs. However, a given percentage difference in productivity is only half as large in terms of standard deviations as the same percentage difference in 180-day weight. At a given level of inbreeding expected line differences in productivity are only about two-thirds as large in terms of standard deviations as the line differences expected in weight at 180 days.

Increasing the inbreeding of the parents beyond 20 to 30 per cent accomplishes little further reduction in the amount of data necessary to demonstrate differences between two unrelated lines with $P = .05$ or .10, in spite of the continuous increase in D and decrease in A, B, and C as inbreeding advances. (See table 4.) This stems from the fact that the size of the variance ratio (F) required for significance increases curvilinearly upwards as the degrees of freedom for error decline. Even for the 1 per cent level of significance, the reduction in numbers is negligible for inbreeding beyond 40 to 50 per cent. Epistasis and dominance may cause the numbers required for statistical significance to diminish somewhat more rapidly with higher inbreeding than is shown in table 4. This curvilinearity of F and its bearing on the relation of inbreeding intensity to the requirements for *significance* should not be confused with the fact that the variation between group averages is expected to increase linearly with inbreeding, as shown in figure 1.

Expected differences between inbred lines are large enough that it may be

possible to compare the inbred lines themselves while they are being produced, and without designing special tests for that purpose. In order to increase the inbreeding rapidly, only one or two sires are being used per line each season in most of the inbred lines at Experiment Stations now cooperating in the Regional Swine Breeding Laboratory. Even in the "one-sire" lines, which are most numerous, more than one sire is often used because of temporary incapacity or for other reasons. Most difficulty in comparing lines on the basis of routine data being accumulated while the line is being formed will be experienced with characters like the productivity of sows, which are observed on only a few of the pigs. As an example, let us use inbred lines in which 2 sires produce progenies of 5 litters each, but only about 8 gilts per line are needed for replacements each season. The 8 gilts are likely to be saved from only about 4 litters so that on the average $n=2$ and $d=2$ for productivity information as compared to $n=6$ and $d=5$ for 180 day weight. With these numbers and with parental inbreeding at 20 per cent, table 4 calls for data from 2 seasons for 180 day weight and from 5 seasons for the productivity index of sows. If only one sire is used per season in each 10 sow herd, data from about 4 seasons for 180 day weight and from 7 seasons for productivity of sows would be required. Comparable requirements when data are obtained on as many as 5 lines each season are 2 and 4 seasons for "two-sire" lines and 3 and 5 seasons for "one-sire" lines. To expect significant line heterogeneity in the whole sample of "two-sire" inbred lines compared, the average number of lines required in data from a single season is as follows:

Inbreeding of parents (f')		.0	.1	.2	.3	.4	.5	.6	.7	1.0
Number of lines	Weight—180 days	16	9	6	5	4	3	3	3	2
	Productivity index	150	60	35	21	16	13	11	9	6

Comparisons of Linecrosses

When all gene effects combine additively, the differences expected between unrelated linecrosses are

$$\sqrt{\frac{(V_g+2V_m)}{2(V_g+V_m)}}$$

as large as those between inbred lines. This amounts to $\sqrt{\frac{1}{2}}$ for the productivity index of sows, but is slightly larger (.76) for weight at 180 days. Heterosis would increase the size of differences between linecrosses relative

to those between inbred lines, but the standard errors of those differences would be expected to increase in about the same proportion.

The numbers required for statistical significance are larger than those given in table 4 by about one-third to one-half for 180-day weight and by one-half to three-fourths for productivity index of sows. Even in the unlikely event that productivity information can be obtained for an average of two gilts from every linecross litter, data from about twice as many seasons will be necessary to expect significant linecross differences in productivity as in weight at 180 days. The numbers required are reduced very little by increasing the inbreeding of the parents beyond 30 to 40 per cent.

In comparing linecrosses which have one line as the common male parent, the number of litters required for significance is no larger than for comparisons between unrelated linecrosses if each boar of the one inbred line sires about the same proportion of the litters in each of the linecrosses. Expected differences are only

$$1/2\sqrt{\frac{V_g+4V_m}{V_g+V_m}}$$

as large as those between inbred lines, but the sire differences which make the C component of variance do not appear in the mean square between linecrosses. Hence, the mean square between litters within sires with its larger number of degrees of freedom can be used for error. However, in comparisons between linecrosses produced by mating different sows of one line to boars of several unrelated lines, differences expected are only

$$1/2\sqrt{\frac{V_g}{V_g+V_m}}$$

as large as those between inbred lines, and sire differences are included in the mean square between linecrosses. Hence, in these comparisons the numbers of litters required for significant differences in weight or productivity are nearly twice as large as in comparisons between unrelated linecrosses.

When comparisons of first generation linecrosses are conducted at the station where the inbred lines are maintained, the same sires can be used for both inbreeding and linecrossing. This may make it economically feasible to keep the number of litters per sire small and the number of sires per line relatively large, thus obtaining the maximum amount of information per litter on comparisons between linecrosses. It will also permit comparing linecross animals with inbred animals of the lines crossed. In such comparisons, the mean square appropriate for error is that between litters within sires, if every boar of one line sires about the same proportion of inbred as of linecross litters.

Comparisons of the average performance of two of more lines in crosses with a definite set of other inbred lines are likely to require larger numbers of animals than the similar comparisons of different topcrosses on outbred stock. This happens because the standard error of average differences in linecross performance would include any variance due to "nicking" (i.e., non-additive variation between linecrosses). Thus the degrees of freedom for error are likely to be limited by the number of linecrosses for each line rather than by the number of sires used for each linecross.

Comparisons of Topcrosses

When all gene effects combine additively, the ratio of differences between topcrosses of unrelated lines to those expected between the inbred lines themselves, as given in table 4, is

$$1/2\sqrt{\frac{V_g}{V_g+V_m}}.$$

This amounts to $\frac{1}{2}$ for the productivity index but is slightly less (.46) for 180-day weight. Numbers required for statistical significance of differences between two topcrosses are from two to three times as large as those given in table 4 for comparisons between two inbred lines. Little further reduction in the numbers required is accomplished by delaying topcross testing in order to increase the inbreeding of the lines beyond 40 to 50 per cent.

If topcross comparisons of inbred lines are obtained in cooperating commercial herds, it seems unlikely for practical reasons that more than one sire progeny could be obtained per topcross in each herd-season replication. However, each sire's progeny might well contain as many as four litters. At this rate, the average number of herd-season replications (yk) necessary to expect statistical significance in comparing two topcrosses of unrelated lines inbred 30 per cent ($f' = .3$) would be about 10 for 180-day weight, but would be 16 for productivity index of sows, even if productivity records could be obtained for about two gilts from every topcross litter.

Comparisons of Individual Topcrosses with Outbred Stock

Differences expected in comparisons of individual topcrosses with outbred stock which is equal in performance to the average of all topcrosses are only

$$\sqrt{\frac{V_g}{8(V_g+V_m)}}$$

as large as those expected between two unrelated inbred lines. This fraction is .35 for the productivity index of sows and .33 for 180-day weight.

The numbers required would be something like four times those given in table 4 for comparisons between two inbred lines, and one and one-half to two times those for comparisons of two topcrosses.

If selection of the foundation stock and subsequent selection within lines was really very effective, it could have produced a real difference between the average of all topcrosses and that of commercial outbred stock. Also, a prime object of comparisons between topcrosses and outbred stock is to discover whether topcrosses of some inbred lines are enough better than commercial stock to give them a real economic advantage. Hence, these comparisons probably should include only topcrosses of lines which have shown most promise in previous comparisons between lines, and each topcross should be tried in enough replications so that a difference which is large enough for economic importance will be statistically significant. The approximate numbers required for the significance of a given absolute difference in weight or productivity can be obtained from table 4, since the numbers in this table are determined almost entirely by the size of the difference expected between groups. For example, if one sire progeny of four litters is raised per season for each topcross and each group of outbreds, the number of replications required to detect 10 per cent differences (18 lbs. in weight and 2.74 units in productivity index) with $P \leqq .05$ is about 6 for 180-day weight, but is 14 for productivity index when productivity records are obtained for about two gilts from every litter.

Table 4 can be used to obtain a rough estimate of numbers required for the significance of a given absolute difference in weight or productivity for other kinds of comparisons between groups with different parents, such as those between two pure breeds, two families, two breed crosses, etc.

Summary

In an unselected population, additive genetic differences between unrelated inbred lines are expected to average $\sqrt{2}$ times as large as those between unrelated first generation linecrosses, 2 times those between topcrosses of unrelated inbred lines, and $\sqrt{8}$ times those in comparisons of individual topcrosses of unrelated lines with outbred stock. As the homozygosity of the inbred lines increases, average differences between inbred lines approach a maximum which is $\sqrt{2}$ times as large as average genetic differences between unrelated individuals in an outbred population, when all gene effects combine additively. Comparable maxima are 1 for linecrosses, $\sqrt{\frac{1}{2}}$ for topcrosses, and $\frac{1}{2}$ for comparisons of individual topcrosses with outbred stock. Non-additive gene effects would make differences between groups larger, especially as the lines become more highly inbred. Prior selection, particularly elimination of inferior lines, would make differences between groups

smaller, except in comparisons of individual topcrosses with outbred stock.

Conclusions reached for swine breeding experiments concerned with weight of pigs at 180 days of age and the productivity of sows are as follows:

1. The average numbers of animals necessary for the statistical significance of expected intra-herd and intra-season differences between two groups have the following approximate ratios to the numbers required for differences between two inbred lines: 1.5 for linecrosses; 2 to 3 for topcrosses; and about 4 for comparisons of individual topcrosses with outbred stock.

2. For characters with as much environmental variation as weight and productivity, the homozygosity of the lines and the kind of comparison have little effect on the standard error of differences between groups and hence do not have much effect on the numbers required for the significance of a given absolute difference.

3. When all gene effects combine additively, little further reduction in the average numbers required for the 5 or the 10 per cent level of significance is accomplished by advancing the inbreeding of the parents in unrelated lines beyond 20 to 30 per cent for comparisons between the inbred lines themselves, 30 to 40 per cent for those between linecrosses, and 40 to 50 per cent for those between topcrosses. For the 1 per cent level of significance, up to 20 per cent of additional inbreeding will accomplish appreciable further reduction in numbers required. Additional group differences due to dominance and epistasis increase in size as inbreeding progresses, so that numbers required would decline a bit more than this with further inbreeding.

4. Inbred lines should be unrelated if maximum differences between lines are desired. Average differences between related lines are reduced to

$$\sqrt{\frac{f-f_0}{f}}$$

times what they would be between unrelated lines, where f is Wright's (1921) inbreeding coefficient for the lines and f_0 is the average inbreeding which would result from mating animals of one line to those of another. Inter-line relationship reduces average differences between topcrosses, between linecrosses, and between individual topcrosses and outbred stock in the same proportion as those between inbred lines.

5. About twice as many herd-season replications and considerably more work will be required to demonstrate significant differences in sow productivity than in 180-day weight, since productivity is less heritable than weight, and its observation is more expensive and is limited to less than half of the animals.

6. In comparing groups having no parents in common, fewest litters are needed for statistical significance if no parent has more than one litter. How-

ever, the cost of sire service, the mating system, and other factors, will modify that in determining what experimental plan will provide significant results most economically.

Literature Cited

Winsor, C. P., and G. L. Clarke. 1940. A Statistical Study of Variation in the Catch of Plankton Nets. Sears Foundation: Jour. Marine Res. 3: 1–34.
Wright, S. 1921. Systems of Mating. Genetics, 6: 111–178.

ABSTRACTS OF PAPERS TO BE PRESENTED AT THE THIRTY-FIFTH ANNUAL MEETINGS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings will be held at the Hotel Sherman in Chicago, Illinois, on December 1 and 2, 1942. The programs of the general sessions will be devoted to discussion of ways in which animal husbandry work can best support the war effort and other timely topics. Because of the emergency only a few papers have been submitted in some sections and none in others, hence certain sections will be combined and others omitted. These and other necessary changes will be shown in the printed program of the meetings. Many abstracts exceeded the 250 word limit and it has been necessary for the Editor to make arbitrary reductions because the time element in meeting the printing deadline prevented consultation with the authors. Sections are arranged in alphabetical order and abstracts within each section are arranged alphabetically by name of the senior author.

Animal Breeding Section

A. B. Chapman, *Chairman*

ANALYSIS OF A BREEDING PROGRAM—GROWTH, PRODUCTION AND HEALTH. J. W. Bartlett, S. Margolin and O. L. Lepard, *New Jersey Agricultural Experiment Station.*

A method is presented for making a complete and concise inheritance study of a dairy cattle breeding project. It is so organized to further the selection of blood lines which can be relied upon to transmit desirable growth, health, and production factors. Several characteristics are examined and set forth in the following three groups—(a) Growth: calf, 2 yr. old and mature measurements (weight, height and heart girth), age at first lactation and type classification. (b) Production: fat test, milk production and total fat. (c) Health: conception rates number of lactations, mortality of calves and longevity. The inheritance of these factors may be studied for influence of outcrossing, linebreeding, and inbreeding. Three charts are utilized based on the groups cited. On each chart, data is presented by cow families and by the mean performance of the daughters of each sire represented in any given family. Improvement or no change in performance of a daughter with respect to her dam is indicated in blue date figures; performance of a daughter equal to or better than her sire is indicated by a blue name or cow number. Inferior performance with respect to dam or sire is indicated similarly, in red type. Black type is used to indicate non-comparable or incomplete data. The use of this tri-color system readily emphasizes the desirable and undesirable characters.

EFFECT OF PROGENY TESTING ON PROGRESS FROM SELECTION WITHIN CLOSED HERDS. G. E. Dickerson and L. N. Hazel, *United States Department of Agriculture and Nebraska Agricultural Experiment Station.*

A quantitative evaluation is presented of factors affecting progress from selection within livestock populations closed to outside breeding, using data on heritability of various economic traits. It demonstrates that progeny testing can seldom increase rate of improvement, and emphasizes (1) more accurate early selection of breeding stock based on pedigree, individual merit, and merit of close relatives, and (2) keeping at a minimum the age of parents when offspring are produced. The mean rate of improvement (ΔG) expected is:

$$\Delta G = \frac{\Delta S_1+(N_2+\cdots+N_n)\Delta S_2+\cdots+N_n\Delta S_n+\Delta D_1+(M_2+\cdots+M_n)\Delta D_2+\cdots M_n\Delta D_n.}{2T \text{ OR } (N_1Y_1+\cdots+N_nY_n)+(M_1Z_1+\cdots+M_nZ_n)}$$

T is average age of parents when offspring are born. The mean additively genetic superiority of animals saved in the 1st selection over the whole group from which they are chosen is designated by ΔS_1 for sires and ΔD_1 for dams; mean additional genetic superiority of animals saved in a 2nd culling of those saved in the 1st by ΔS_2 and ΔD_2; etc., for n successive cullings. N_1 is proportion of all offspring by sires which have been culled once, and Y_1 is average age of these sires when their offspring are born; N_2 and Y_2 are the corresponding proportion and age for offspring of sires which have been culled twice, etc. M_1, $M_2 \cdots M_n$, and Z_1, Z_2, $\cdots Zn$ are the same proportions and ages for dams. T can be kept at a minimum when selection is based on pedigree, individual merit, merit of collateral relatives, or a combination of these. Any gain in ΔS or ΔD from progeny test selection may easily be more than cancelled by concurrent increase in T.

SELECTION FOR GROWTH RATE AND PRODUCTIVITY IN CLOSED HERDS OF SWINE. G. E. Dickerson and L. N. Hazel, *United States Department of Agriculture and Nebraska Agricultural Experiment Station.*

Expected rate of improvement is compared for various methods of selection for 180-day weight and productivity within "closed" herds of swine. Increases of one pig raised per litter and of 25 pounds in 180-day weight are presumed to be equally important. Data used are from the Iowa and Nebraska Station herds of the Regional Swine Breeding Laboratory. Progress is nearly maximum when boars are replaced annually and selection is based on pig's own 180-day weight and dam's productivity. Extra progress obtainable by considering the 180-day weights of litter mates in selection is negligible. Progress is reduced by using progeny tests for boar selection. About 95 per cent of the total possible improvement is obtained when one-third of all boar pigs are saved in a first culling based on 56-day weight and dam's productivity, and the second culling is based on 180-day weight and dam's productivity. Progress falls off rapidly as fewer than one-sixth of the boar pigs are saved in the first culling, to only 60 per cent of the total possible when final boar selections are made then. Progress is nearly maximum when gilts are selected on 180-day weight and the dam's productivity and all gilts are replaced annually. Less than 5 per cent more progress can be expected when the optimum proportion of sows ($\frac{1}{4}$) are saved for one additional year in a second culling based on the sow's own productivity and 180-day weight, and mean 180-day weight for her first litter.

RESULTS TO BE EXPECTED FROM SELECTION ON A FAMILY BASIS. Jay L. Lush, *Iowa State College.*

The consequences to be expected from selecting solely on individuality, or solely on family average, or on the optimum combination of attention to both, were deduced from the biometrical relations existing between genotypes and phenotypes of family members. A family is defined as a group all equally related to each other. Examples would be a set of full sibs, or a set of half sibs. Family selection will make less rapid progress than individual selection either when the characteristics are highly hereditary or when the phenotypes of members of the same family are closely correlated because of common environment. If the phenotypic correla-

tion exceeds the genetic correlation between family members, the family average should receive negative attention, which is equivalent to judging the individual partly on its deviation from its family average and partly on its own individuality. If the optimum combination of family and individual attention is to make progress much more rapid than it would be under selection for individuality alone, the phenotypic correlation between family members must be low and the genetic correlation between them must be high. The genetic correlation can be made higher than .375 for those which are not maternal sibs and higher than .50 for full sibs only by inbreeding. The phenotypic correlation will be low only for characteristics which are easily and strongly influenced by ordinary variations in environment (as most economically important characteristics are) or by accidents of development, and if there are no environmental correlations between family members.

EXPERIMENTAL ATTEMPTS TO MODIFY THE SEX RATIO IN RABBITS AND PIGS. Hugh C. McPhee and Orson N. Eaton, *United States Department of Agriculture.*

An experiment to determine the effect of acid and alkaline douches on sex ratio was conducted with rabbits and swine. Female rabbits were divided into 10 groups, each group mated to a single male. Each of these groups was sub-divided into three groups, one treated with lactic acid and one with sodium bicarbonate, the third untreated. Treatments were shifted so that each doe would receive all three treatments. Each buck sired approximately the same number of litters for each treatment. Of 2322 young sexed, 799 with 53.4 per cent males, 703 with 50.1, and 820 with 50.2 per cent males were born in the untreated, acid and alkali groups respectively. With swine, the pH of the semen was altered in the alkaline or acid direction with sodium hydroxide or lactic acid respectively before artificial insemination. The pH of the semen as it came from the boar averaged 7.25. That adjusted in the alkaline direction averaged 8.65, and the acid 5.79. Thirteen litters were farrowed in the alkali group with 58 males and 63 females or 47.9 per cent males. In the acid group the percentage was 45.9 with 45 males and 53 females. The normal sex ratio for swine is about 52 per cent males. Statistical analyses of the results indicate that the sex ratio was not altered significantly by treatment with lactic acid or an alkaline solution, applied either as a vaginal douche in rabbits or added directly to the semen before insemination in swine.

THE BREEDING STRUCTURE OF THE PUREBRED ABERDEEN-ANGUS CATTLE POPULATION IN THE UNITED STATES FROM 1900 TO 1939. H. H. Stonaker, J. C. Holbert, and Jay L. Lush, *Iowa State College.*

Two thousand pedigrees of animals born in the United States in 1900, 1910, 1920, 1930, and 1939 were analyzed by the Wright-McPhee sampling method of determining inbreeding and relationship coefficients relative to the foundation animals. The average inbreeding percentages of the respective samples are 8.9, 12.7, 10.8, 14.2, and 11.3. The average rate of increase is .3% per generation. The average percentage relationship (inter-se) between random selected pedigrees for the five samples is 9.4, 16.3, 12.2, 16.1, and 13.3. From this one would expect the inbreeding to be about 60 per cent of what was actually found. Breeders' tendencies to linebreed, to use home-bred animals, and to use animals bred in their own localities are some of the more important factors responsible for the breed tending to be separated into several partially isolated sub-groups. Actually the breeders use about 2300 sires per generation, whereas if the breed had been mating absolutely at random only 38 sires would have been necessary to cause the inbreeding to rise at its present rate. Black Prince of Tillyfour (77) is 24.1% related to the breed (practically equivalent to a grandsire). Relationships of other important animals are Hanton (80), 21.3%; Rob Roy MacGregor (106), 14.9%; Grey Breasted Jock (113), 15.5%; Earl Marshall (183780), 14.0%; Black-cap Revolution (287269), 12.0%. Over 60% of the foundation animals were bred by Hugh Watson, Alex Bowie, William Fullerton, William McCombie, and Lord Panmure; 50% of the foundation animals were bred in the Watson herd alone.

EXPERIMENTAL MODIFICATION OF ESTRUAL PHENOMENA IN EWES. E. J. Warwick and L. E. Casida, *University of Wisconsin.*

Forty-nine ewes were each injected subcutaneously with follicle-stimulating extracts and then intravenously with luteinizing or unfractionated extracts of sheep pituitary. Thirty-five ewes were injected so that the treatment terminated on the 17th day of the estrual cycle. Their inter-estrual periods were shortened an average of 0.86 days and their estrual periods were prolonged an equal amount. The natural variation in the estrual cycle and the inter-estrual interval was not affected; neither was the repeatability of the estrual cycle. Treatment during the early part of the estrual cycle did not initiate estrual behavior in any of five ewes. Estrual behavior was induced in only one of nine ewes treated during anestrum. Estrus was apparently inhibited when unfractionated extracts were administered to two ewes so that the treatment terminated on the 17th day of the cycle. Estrus was prolonged in one of two ewes when treatment with an unfractionated extract was begun during natural estrus. None of six ewes showed estrual behavior following a single injection of pregnant mare serum during anestrum. Two of four ewes showed estrus when a second injection of PMS was given 16 days later. Stilbesterol was administered to thirty-two spayed ewes in dosages ranging from 100 to 50,000 rat units daily. A dosage of 400 rat units daily appeared minimal for production of estrus within two days. No gross pathology of the vital organs appeared from any of these dosages when administered for five successive days.

Conference on Artificial Insemination

Clair E. Terrill, *Chairman*

THE RELATION OF CERTAIN FUNDAMENTALS OF SPERM METABOLISM TO THE PROBLEM OF SEMEN STORAGE FOR ARTIFICIAL INSEMINATION. Henry A. Lardy and Paul H. Phillips, *University of Wisconsin.*

In continuation of previous work on the metabolism of ejaculated bovine spermatozoa the following results were obtained. 1. In confirmation of our previous observations, two separate metabolic processes, i.e. glycolysis and oxidation. furnish energy for motility. These two processes have been separated by means of certain metabolic inhibitors. Cyanide, malonate and benzoate completely inhibited motility when the only energy source available was via the oxidative process. These inhibitors were almost completely without effect on the ability of spermatozoa to use the glycolytic process as a source of energy. 2. Although spermatozoa contain no citric dehydrogenase, citrate has under aerobic conditions, a beneficial effect on motility that it does not demonstrate under N_2. Citrate decreases the oxygen consumption of the spermatozoa. 3. After prolonged storage spermatozoa which have lost motility cannot be revived by replenishing the medium with substrates and/or bringing the pH back to optimum. 4. That loss of motility may be the result of loss of dialyzable coenzymes is indicated by the observation that adenylic acid prolonged motility of bull spermatozoa stored in yolk-buffer. Addition of cozymase was without effect on motility. 5. Spermatozoa are more resistant to temperature shock when suspended in yolk-buffer than they are in plain buffered solutions or semen alone.

Beef Cattle Section

J. H. Knox, *Chairman*

FERTILITY IN RANGE BEEF CATTLE. A. L. Baker and J. R. Quesenberry, *United States Department of Agriculture, Miles City, Montana.*

Per cent of pregnancies and of calf crop at weaning were 85.3 and 80.6 per cent respectively in 4,710 cow breeding years at the U. S. Range Livestock Experiment Station from 1925 to 1942. Highest fertility was in 1939 when 94 per cent of 298 cows were pregnant and calf crop weaned was 90.0 per cent. Two low points in 1935 and 1937 followed years of extreme drought during the breeding season. Fertility and calf crop at weaning were 77.5 and 71 percent in 1935 and 68.4 and 65 in 1937. Relation of age to fertility was studied in 412 cows born from 1925 through 1931, that were bred to calve at 3 years and dropped calves from 1928 through 1942. Numbers calving from 3 through, 11 years of age were 350, 320, 293, 243, 178,

150, 111, 64, and 30 respectively. Per cents of pregnancies were 85, 80.6, 85.9, 84.4, 81.3, 85.2, 86.7, 84.2, and 81.1 at the respective ages and per cents of living calves at birth were 81.1, 77.6, 83.3, 81.6, 79, 83.5, 85.2, 77.6, and 81.1. Thus, lowest fertility was observed at 4 years and highest at 9. Cows that failed to conceive or to produce living calves for two successive years were culled. Because of strict culling fertility was maintained at a satisfactory level in the older cows. Of 77 cows barren at 4 years, 31 were also barren at 3. These animals might be detected earlier by breeding to calve at 2 years, but this practice needs further study before it can be recommended.

EFFECT OF SUPPLYING PHOSPHORUS TO CATTLE, GRAZING A PHOSPHORUS-DEFICIENT RANGE, UPON BEEF PRODUCTION. W. H. Black and N. R. Ellis, *United States Department of Agriculture* and J. M. Jones, *Texas Agricultural Experiment Station.*

This paper covers investigations conducted in south Texas by the Bureau of Animal Industry, the Texas Agricultural Experiment Station, and the King Ranch, in which range cattle were fed phosphorus in the form of bonemeal with and without a number of trace minerals and disodium phosphate. Analyses of the vegetation and blood of range cattle made previous to the administration of phosphorus to the cattle indicated that a phosphorus deficiency existed. Feeding approximately 6.5 grams of phosphorus to dry cows and 14 grams to lactating cows daily (6 times per week) prevented aphosphorosis in cattle grazing phosphorus-deficient ranges. There were no significant differences in the results between bonemeal and disodium phosphate as sources of phosphorus. Trace minerals such as manganese, copper, iron, zinc, cobalt, and boron fed with bonemeal resulted in no additional benefits over bonemeal by itself. Analyses of blood taken at regular intervals indicated a phosphorus deficiency in the ration when the inorganic phosphorus content was less than 4.0 milligrams per 100 cubic centimeters of blood. Blood from cows fed phosphorus was usually safely above this level whereas that from control cows was seldom above 4.0 milligrams. Phosphorus increased percentage calf crop about 30 per cent and weaning weights about 70 pounds per calf on the average. The increase in weaning weights was due to increased milk flow of the supplement-fed cows.

RELATIONSHIP OF MILK PRODUCTION OF MILKING SHORTHORN DAMS TO THE CARCASS QUALITY OF THEIR STEER PROGENY. A. C. Cook, W. H. Black, Bradford Knapp, Jr., and R. W. Phillips, *United States Department of Agriculture.*

Data on 83 head of Milking Shorthorn steers and their dams were used in this study. Milk records were corrected to 4 per cent fat and converted to a mature basis. Correlation between milk production of dam and the muscle bone ratio of the carcass of steer offspring was −.07, and was not significant. Correlation between milk production and efficiency of gain of offspring was 0.10, but was not significant. Correlations between milk production and per cent of fat in carcass and carcass grade were −.17 and −.20, respectively. These correlations approach significance and indicate a tendency for offspring of high-producing cows to lack the finish and quality of steer offspring of lower-producing dams. The progeny of dams with a level of production up to approximately 8,000 pounds of 4 per cent milk at maturity show a decrease in carcass grade as milk production increases, but from that level upward, there is no further decrease in carcass grade of the steers. Milking Shorthorn steers, taking off milk at approximately 500 pounds weight and fattened to 900 pounds, should produce carcasses grading on the average approximately middle Commercial (middle Medium). These studies indicate that there is a possibility of increasing carcass grade and percentage of fat in the carcass of Milking Shorthorn steers by selection of breeding animals that are not only capable of producing up to approximately 8,000 pounds of milk at maturity but steer progeny that will produce carcasses grading top Commercial or better.

THE LAXATIVE NATURE OF SOYBEAN OILMEAL IN RATIONS FOR FATTENING CATTLE. Irvin F. Edwards, R. R. Snapp, and W. E. Carroll, *Illinois Agricultural Experiment Station.*

No study of this question has been reported in the literature, but many practical feeders

have believed soybean oilmeal has given them trouble. Cattle were fed in small groups, individually and in pairs, and feces were collected from the individual steers over a period of three years. Fourteen different lots of soybean oilmeal were tested, as well as ground soybeans, linseed meal and cottonseed meal. Soybean oilmeal did not produce an undue laxative condition in cattle even when fed with shelled corn in a ratio of 1:2.33. (A ratio of 1:7 is used as a check ration at the Illinois Station.) Soybean oilmeal was less laxative than ground soybeans, slightly more laxative than cottonseed meal, and about equal to linseed meal in laxative properties. The time of processing soybeans after harvest had no significant influence on the laxative nature of the meals.

USING PROTEIN SUPPLEMENTS AS A PARTIAL SUBSTITUTE FOR CORN IN THE RATIONS OF FATTENING CATTLE. Fred C. Francis and W. E. Carroll, *Illinois Agricultural Experiment Station.*

Soybean oilmeal has occasionally been available at a lower cost per pound than corn. Greatly increased soybean production for oil purposes, now demanded, suggested that this condition might be reached again soon. Three lots of cattle were fed different ratios of corn to soybean oilmeal, 2:1, 4:1, and 7:1, the last being the "check" ration of this Station. The cattle were short two-year-olds in good feeder flesh at the start, in the spring of 1942. Many feeders have complained that even small amounts of soybean oilmeal have caused their cattle to scour badly, to go off feed frequently, and in general have given rather poor results; however, none of these troubles ever were obvious in the cattle on test, and observations indicated that the "check" ration lot was off feed more times than either of the other two lots. The cattle in the 2:1 ratio lot received as high as 6.8 pounds of soybean oilmeal per day. Some have thought that a high number of liver condemnations may be caused by soybean oilmeal. There was only one condemned liver in the entire group of 30 steers from a steer in the check lot. All lots of cattle gained practically the same per day; and cost per hundredweight gain showed very little variation. If soybean oilmeal is worth $36 a ton when fed in the ratio of 7:1, it proved to be worth $59.79 when fed in a ratio of 4:1, and was worth $52.79 when fed as one-third the concentrate mixture.

COMPARISON OF PROTEIN SUPPLEMENTS FOR YEARLING STEERS. R. B. Hinman, F. B. Morrison, J. I. Miller, C. S. Hobbs and J. J. Wanderstock, *Cornell University.*

Experiments with fattening yearling steers were conducted to determine the relative value of four protein supplements (linseed meal, corn gluten meal, soybean oilmeal, and ground soybeans) fed with ground corn, corn silage, and a small amount of mixed hay. Steers have come from four different sources, and included stockyard Shorthorns, Herefords purchased from the ranch in Texas, Aberdeen-Angus purchased from local breeders, and Herefords purchased from the Kansas City stockyards. There was a slight tendency for linseed oil meal to produce the most rapid gains and for corn gluten to produce slightly less rapid gains. There are no appreciable differences between the lots in the amounts of feed required per 100 pounds of gain, in the feed cost per 100 pounds of gain, in the selling price per hundredweight, or in the dressing percentage. Individual grades of the animals on foot at the end of the trial placed linseed meal lots slightly first and the corn gluten meal lots were the last. The grader maintained that the soybean oil meal lots were firmer in finish, but he liked the linseed oil meal group best. This he claimed was due to the so-called "bloom." Although others have had poor results with ground soybeans as a protein supplement for young cattle, it is interesting to note that, under the conditions of these experiments, raw soybeans compare favorably in all respects with the other protein supplements.

DIFFERENCES IN PERFORMANCE BETWEEN SEXES IN OFFSPRING OF BEEF BULLS. Bradford Knapp, Jr. and Ralph W. Phillips, *United States Department of Agriculture.*

There is a belief among breeders that some beef sires tend to produce better male than female calves, or better females than males. Breed history seems to bear out this belief for in each breed some bulls have been noted for outstanding sons and others for their daughters. The purpose of this study was to determine whether this apparent difference was measurable

in weights, gains, or scores of offspring of different sires. Data from the U. S. Range Livestock Experiment Station (U.S.D.A. and Montana Experiment Station cooperating) during 1939 to 1942 were used. Three characters were selected, weaning weight, score at weaning, and gain on feed for 140 days. Significant differences between sires were observed in weaning weights in 1941 but there was not a significant difference between sexes by the same sire. In 1940 one sire produced heifers weighing 27 pounds more than the male calves at weaning and this sire in 1941 produced proportionately heavier heifers than steers when compared with other bulls. In scores, there was no significant sire×sex interaction. In gains after weaning, there was a significant difference between sires and a significant sex×sire interaction. When sire differences were tested against sex×sire interaction, there was no difference between sires. This study indicates that in gains after weaning some sires apparently produce better gaining heifers than steers, or better gaining steers than heifers and that, if true superiority is to be demonstrated, data on both sexes are desirable.

BREEDING METHODS FOR THE PRODUCTION OF HYBRID BEEF CATTLE ALONG THE GULF COAST. A. O. Rhoad, *United States Department of Agriculture, Jeanerette, La.*

Results of twenty-five years of crossbreeding investigations at the Iberia Livestock Experiment Farm have indicated that where purebred bulls are used on native or grade beef type foundation cow herds best results were obtained by first grading-up the foundation herds, crossbreeding first generation heifers to the Brahman and then backcrossing the hybrid heifers to the standard beef breed, thus producing animals possessing $\frac{3}{4}$ beef breed, $\frac{1}{4}$ Brahman and $\frac{1}{8}$ foundation breeding. A second satisfactory breeding method was backcrossing the first generation grade heifers to the beef breed and crossbreeding the second generation to the Brahman, thus producing the $\frac{1}{4}$ Brahman, $\frac{3}{4}$ standard beef breed and $\frac{1}{8}$ foundation animal. Infusion of beef-type breeding before crossbreeding to the Brahman proved more satisfactory than first crossbreeding to the Brahman and then grading-up to the beef breed. Infusion of Brahman blood in the first generation and subsequent grading-up proved more satisfactory than grading-up to the beef breed without the use of Brahman blood. Superior quarterbreds and $\frac{3}{4}$–$\frac{5}{8}$ breds were produced by first crossbreeding purebreds to the Brahman and backcrossing the halfbred hybrid heifers to the standard beef breed. Halfbred heifers, when mated to the quarterbred ($\frac{1}{4}$ Brahman $\frac{3}{4}$ standard beef breed), produced $\frac{3}{8}$–$\frac{5}{8}$ offspring that proved somewhat superior to the reciprocal $\frac{3}{8}$–$\frac{5}{8}$ breds whose dams were quarterbreds out of purebred cows and sired by halfbred bulls.

Dairy Cattle Section

W. E. Krauss, *Chairman*

THE EVALUATION OF GRASS SILAGE AS A SUCCULENT FEED. C. B. Bender, *New Jersey Agricultural Experiment Station.*

Grass silage is a term given to any crop other than corn and sorghum that is put into the silo. Alfalfa silage as a term is as indefinite as alfalfa hay. It may vary from an equivalent of U. S. No. 1 grade to lower than sample grade. The silage also varies because of the amount of preservative, condition of the silo, moisture content of the plant at time of ensiling and because of other factors. Intake of grass silage by mature animals may vary from 10 to 110 pounds a day depending on palatability, moisture content and previous feeding experience of the animals. Response of the animals is tied up with quality of the silage and the way in which the rations are balanced. In interpreting results of grass silage feeding experiments in different sections of the country it is difficult for investigators to understand the wide differences in results with apparently similar crops. Because of these facts and in order to better coordinate research it is suggested that grass silage be classified for feeding experiments as to: Crop ensiled (if mixtures of species, specify approximate percentage of each); Preservatives used; Quality classification (pH and Butyric acid content); Palatability. From the standpoint of research on ensiling methods, it is suggested that the following data be included also: Methods of harvest-

ing and rate of fil'ing; Standardized sampling set up to measure silage losses; Type and condition of silo used; Cost figures in terms of man, team and machine hours.

THE VALUE OF SHORT-TIME RECORDS FOR CULLING AND FOR PROGENY TESTING OF DAIRY CATTLE. C. W. Kennedy and D. M. Seath, *Louisiana State University.*

Much culling for production takes place before cows finish first lactations. The value of incomplete records of such cows as a basis for culling and progeny testing was investigated, using records of 80 Jerseys and 80 Holsteins within the University herd. Cows selected had complete records for first two lactations. The production of first-calf heifers during the first four months was a good index of what the complete first lactation would be, and also the relative production for the second lactation. The correlation between the short-time records and the complete (305-day) first lactation increased from an average (for milk and butterfat) of .62 for one month to .78 for four months. The short-time records when correlated with complete (305-day) second lactations increased with Jerseys from an average of .40 for one month to .45 for four months. Holsteins averaged .41 for one month and decreased to .30 for four months. The two- and three-month records were also smaller than the one-month. No explanation could be found for this downward trend for Holsteins, except variation due to sampling. Correlations between the complete first and second lactations averaged .54. This is somewhat higher than intra-herd correlations reported from other studies. It is also higher than the correlations between the short-time records and the complete second lactations although in this case the difference was not significant. Short-time records have a definite value in culling or in progeny performance testings. Such records were only slightly less valuable than were complete records in predicting production for following lactations.

THE REPLACEMENT VALUE OF COTTONSEED MEAL IN A GOOD DAIRY RATION. A. H. Kuhlman and W. D. Gallup, *Oklahoma A. and M. College.*

Three experiments, including a total of 32 cows, have been completed to determine the value of cottonseed meal when it is fed in excess of the amount required to meet the protein requirements of dairy cattle. The concentrate mixture fed in the check ration consisted of 400 pounds ground No. 2 corn, 200 pounds ground oats, 200 pounds wheat bran, 100 pounds cottonseed meal (43% protein), and 9 pounds salt. In the experimental ration, cottonseed meal replaced 44.5% of this concentrate mixture and constituted slightly more than 50% of the total concentrates fed. Alfalfa hay, U. S. No. 1, extra green, was fed as the sole roughage. When fed the check ration, the cows on the average produced 29.96 pounds of 4% fat-corrected milk daily and consumed 41.6 pounds of the concentrate mixture and 68.4 pounds of alfalfa hay for each 100 pounds of 4% milk. On the experimental ration the cows produced an average of 30.44 pounds of 4% milk daily and consumed 22.5 pounds of the concentrate mixture plus 18.0 pounds of extra cottonseed meal, or 40.5 pounds total concentrates, and 67.4 pounds of alfalfa hay for each 100 pounds of 4% milk. Each 100 pounds of cottonseed meal substituted for the concentrate mixture were equivalent to 109.8 pounds of the concentrate mixture which it replaced. Therefore, when the cost of cotton seed meal does not exceed the cost of corn, oats and bran it may replace them with satisfactory results even when cottonseed meal constitutes one-half of the total concentrates fed with alfalfa hay.

A METHOD OF EQUALIZED FEEDING FOR USE IN LACTATION STUDIES WITH DAIRY COWS. H. L. Lucas and L. A. Maynard, *Cornell University.*

A method of determining concentrate intakes for individual cows during lactation studies which eliminates the possibility of inequalities of feed intake when comparing two or more diets of unequal production value has been devised. In the commonly accepted method, wherein concentrate intake of each individual is based upon her production during an immediately preceding period, a lower feed intake nearly always accompanies the feeding of a poorer diet. If change in diet at the start of an experimental period affects production, inequalities in concentrate quickly result especially when concentrate intakes are adjusted weekly, and the temporary effects may be magnified and prolonged. The concentrate intake of each individual dur-

ing the experimental period is determined in the proposed method on the bases of her production level during a perliminary period and the average decline in production of all cows on experiment regardless of diet. Throughout the experimental period concentrate intakes of all cows are reduced exactly the same percentage of their respective initial concentrate intakes. Use of the proposed method of feeding induced remarkable uniformity of behavior among cows. In a Latin square layout, using 12 cows to test four diets, a difference of less than 3.0 per cent was highly significant. Effects of pregnancy were discernible in lactation curves as early as the eighteenth week in 4 cows, and at the twentieth week in 3 cows. Two low producing cows showed no clear effects as late as the twenty-fourth week. The other 3 animals were not on experiment after the eighteenth week of pregnancy.

CAN ONE PREDICT THE AVERAGE FAT TEST FOR A LACTATION PERIOD ON THE BASIS OF AN INCOMPLETE RECORD? R. P. Reece, *New Jersey Agricultural Experiment Station.*

It is well established fact that after the third month of a lactation period the fat test for any one month tends to be higher than that of the previous month. It is though that this observation is responsible for the belief among dairymen that the average fat test at the end of a lactation period will be higher than the average test at 4 to 8 months. To answer this question for a single herd 70 completed Holstein-Friesian lactation records were obtained from the New Jersey Agricultural Experiment Station herd. The fat test of the first month, the average fat test for the first and second months, and the first, second, and third, etc., through the sixth month was correlated with the average fat test at the end of 10 months. The determined values of r were: first, .53; second, .74; third, .80; fourth, .85; fifth, .87, and sixth .93. Hence, within a herd, the average fat test at the end of the second month of lactation was a good measure of the ability of a cow to secrete milk fat and the average fat test at the end of 6 months was almost identical with the average fat test at the end of 10 months. In this herd, it appears that completed lactation records are not essential before one can determine fairly accurately the ability of a cow to secrete milk fat. (Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Dairy Husbandry.)

A DAM-DAUGHTER COMPARISON OF DAUGHTERS OF HOLSTEIN-FRIESIAN SIRES PROVED IN D. H. I. A. WORK. R. P. Reece and J. W. Bartlett, *New Jersey Agricultural Experiment Station.*

A summary was made of the Holstein-Friesian records published in Miscellaneous Publication No. 393 of the U.S.D.A. There were 1,924 bulls which were proved on the basis of 18,642 dam-daughter pairs, or an average of 9.7 comparisons. The average production of all dams was: 10,691 lbs. milk; 3.4% fat; and 368 lbs. fat. The daughters averaged: 10,389 lbs. milk; 3.5% fat; and 359 lbs. fat. Of the 1,924 sires 833 (43%) neither increased nor decreased milk production. Three hundred and thirteen (16%) increased production and 778 (41%) decreased production. There were 427 sires (22%) that did not change the daughters' fat test, 909 (47%) increased the fat test, and 588 (31%) lowered the test. When fat test was increased 106 sires (5.5%) increased milk production, 364 (18.9%) did not alter milk yield, and 439 (22.8%) decreased milk production. When fat test was not changed 76 (3.9%) sires increased milk yield, 184 (9.6%) did not change milk production, and 167 (8.7%) decreased milk production. When fat test was decreased 131 sires (6.8%) increased milk yield, 285 (14.8%) caused no change in milk production, and 172 (8.9%) decreased milk production. Three hundred and ninety-seven bulls (21%) increased fat production, 797 (41%) neither increased nore decreased fat production, and 730 (38%) decreased fat yield. (Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Dairy Husbandry.)

Extension Section

W. W. Derrick, *Chairman*

THE "PENNY-A-PIG" PROGRAM. E. F. Ferrin, *University of Minnesota.*

The swine industry, one of the most important sources of agricultural income, is unique

among large businesses in that it never has had a strong national organization. Competing products are represented by strong, aggressive national organizations. Efforts to organize swine producers into active, sound state and national groups have been made over a period of many years. The National Swine Growers' Association functioned from about 1915 to 1940 with small membership and inadequate finances. Its influence could not be brought to bear effectively upon the settlement of state and national problems. In 1940 leaders who had been active in the above mentioned Association and Secretaries of the swine record associations formed American Pork Producers' Associated, incorporated in Illinois. Membership consists of 15 state swine producers' associations including all of the leading corn belt swine growing states. A study of methods of financing the organization covered a period of many months. It was decided to ask producers of swine to contribute one cent per pig on all hogs marketed, to be collected through hog marketing channels in the form of a check-off at the time of the sale. The monies are to be used to further work of the National Livestock ar Meat Board to educate consumers of pork products and to protect the swine industry in all matters of public policies. A program to secure signers is underway in several states. It is hoped that sufficient contributions can be secured to finance a sound, democratic organizat n adequately representing the swine interests.

MEASURING RESULTS IN EXTENSION WORK. E. T. Robbins, *University of Illinois.*

A livestock management survey was made in three Illinois counties to test a plan for measuring progress in this project on the basis of improvements in farm practices. Acceptable standards for a number of projects are not difficult to set up. For example, the number of pounds of pork produced per sow in six months is a satisfactory criterion for determining the efficiency of the hog enterprise. Consequently, the county average production of pork for a six months' period can be used to measure the progress made from year to year. To obtain data, a card questionnaire was distributed to the farmers in three counties by the farm advisers. These cards were summarized by Dr. D. M. Hall and the results reported to each farmer with a letter of explanation. Data for 1940 are summarized below, the figures indicating the goal and the averages for Adams, Knox and Bureau counties, respectively: Calves raised per beef cow—1, .9, .9, .9; Bushels corn fed per cow—0, 8.5, 11.9, 17.9; Lambs raised per ewe—1.5, —, —, 1.28; Per cent lambs marketed by June 1—50, —, —, 25.8; Lbs. wool per ewe—10, —, —, 9.4; Pigs per fall litter—8, 6.5, 7.6, 7.8; Pigs per spring litter —8, 6.2, 5.7, 7.1; Lbs. pork per fall litter in 6 months—1600, 1128, 1047, 1058; Lbs. pork per spring litter—1600, 1165, 986, 846. It is planned to repeat this survey at intervals of three to five years and use it to measure the improvement farmers make in their livestock efficiency.

Horse and Mule Section

L. H. Blakeslee, *Chairman*

FACTORS EFFECTING FARM HORSE POWER EFFICIENCY. Ralph S. Hudson and Leonard H. Blakeslee, *Michigan State College.*

Michigan ranks fourteenth among the forty-eight states in horse numbers with approximately 300,000 head. Changing conditions demand that farmers and horse breeders produce the most useful type of horses more efficiently. To meet these conditions the Michigan Agricultural Experiment Station inaugurated work in 1939 to study methods of breeding, feeding, and using horses of medium type as compared with the heavier type. This report is on the feed consumed, gains and sale prices of 28 weanlings of both types purchased in the fall of 1939 and sold at auction in April of 1942. Eight three-year-olds representative of the groups fed and methods in handling were kept for future tests. Results show that medium weight horses consume less feed than heavyweight horses to grow and maintain in similar condition. Weanling colts raised on summer pasture, stacked hay and winter pasture came through in very good condition as three-year-olds and sold for only $9.00 per head less than stall-fed colts receiving grain each winter. Colts confined to box stalls with no exercise cost more to develop and showed more deformities and unsoundnesses.

A GENETIC ANALYSIS OF STAKES WINNING AND POOR PERFORMING THOROUGHBREDS. Dewey G. Steele, *University of Kentucky*.

The pedigrees of 556 Stakes winning and 394 poor performing Thoroughbreds for 1935, 1940 and 1941 were analyzed for inbreeding, inter se relationship within groups, relationship between groups, and relationship to an arbitrary list of famous ancestors. Random 2 line pedigrees were traced to 1748, the foaling date of Matchem. The differences between Stakes winners and poor performers with reference to inbreeding (8.2% and 8.0%), inter se relationship (8.4% and 7.4%), and relationship to selected ancestors are of small magnitude. Current breeding practices are similar to those associated with other classes of livestock.

Meats Section

L. E. Kunkle, *Chairman*

THE RELATION OF ULTRA-VIOLET LIGHT AND TEMPERATURE DURING AGING ON QUALITY OF BEEF. M. E. Ensminger, Jerry Sotola, J. A. McIntosh, Chas. C. Prouty and June Roberts, *Washington State College*.

The use of ultra-violet rays reduced the surface microflora of good quality beef short lions during aging periods of seven and 14 days, employing temperatures of 34° to 50° F. at a relative humidity of approximately 90 per cent. However, the light treatment darkened the color and imparted a greasy appearance to the tallow. Cooking losses, including both drip and evaporation losses, were not significantly affected by treatment. Aging good quality beef short loins at 34° and 50° F. for seven and 14 days with and without ultra-violet light had no significant effect upon the texture and tenderness, whereas frozen storage for six months at 0° F. had a slight tendering effect on the same grade beef. Light treatment produced some slight increase in pH but the results were not significant. By using the U. S. Pharmacopoeia rat technique, it was established that the tallow of beef short loins does contain some Vitamin D, and that the concentration is not affected appreciably by exposing the tallow to ultra-violet light for either ten seconds or seven days at a distance of 46 centimeters.

THE MUSCLE-BONE RATIO AS AN INDEX OF MERIT IN BEEF AND DUAL-PURPOSE CATTLE. O. G. Hankins, Bradford Knapp, Jr., and Ralph W. Phillips, *United States Department of Agriculture*.

One of the greatest problems in determining performance in beef cattle is to devise a measure of merit from the standpoint of meat quality. Considering primarily consumer demands, it was thought that the ratio of lean meat or muscle to bone might offer an index of carcass merit that would be useful in selection. A study was made of the muscle-bone ratio in 55 beef Shorthorn and 80 dual-purpose Shorthorn steers, sired by 7 and 11 bulls, respectively. There was a significant difference between sires within each breed which accounted for approximately 22 per cent of the total variance. Differences between breeds accounted for an additional 16 per cent. No significant correlation was found within breeds between muscle-bone ratio and per cent of separable fat. No relationships were found between live animal measurements (height at withers, heart girth, width of chest, circumference of cannon bone) and the muscle-bone ratio, indicating that selections could not be made on the basis of conformation as it is usually evaluated. There was no relation between the muscle-bone ratio and economy of gain or age of steer at slaughter. There was a significant correlation between some of the carcass measurements and the muscle-bone ratio, but none of the correlations were high enough to be of value in predicting muscle-bone ratio within breeds. It is apparent that selection on the basis of ability to sire offspring having wide muscle bone ratio offers possibilities of improvement without affecting adversely ability to fatten, economy of gain, and conformation.

THE PREPARATION OF MUSCULAR TISSUES FOR HISTOLOGICAL STUDY IN NORMAL AND FROZEN MEAT. Eunice Johnson, F. N. Andrews and C. L. Shrewsbury, *Purdue University*.

A review of the studies which have been made on the histology of meat at Purdue University and other laboratories has revealed that entirely satisfactory techniques for preparing

muscular tissues for microscopic study have not been adequately described. Muscular tissues which have been described as of normal structure and used for comparisons with frozen meat often show excessive shrinkage of individual muscle fibers and obviously do not illustrate the structure characteristic of living muscle. The following points are stressed in the preparation of meat for microscopic study: 1. The tissue must be fixed immediately following the death of the animal or the removal of chilled or frozen meat from storage. 2. Fixation must be rapid and complete and seems to be most uniformly secured with alcohol-acetic acid, chloroform-alcohol-acetic acid and formalin-alcohol-acetic acid fixatives. 3. The time of fixation and dehydration must be rigidly controlled. 4. Time and temperature during infiltration with paraffin must be standardized. 5. More than one fixative should be used for each tissue studied in order that the influence of technique upon the microscopic structure of the meat sample may be evaluated. Specific techniques are described for application to beef muscle studies.

THE EFFECT OF FASTING ON THE YIELD AND CARCASS GRADE OF SPRING LAMBS. C. M. Kincaid, *Virginia Agricultural Experiment Station.*

Twenty grade Southdown lambs were classified into five groups of four each on the basis of fatness and weight. Equal numbers from each group were randomized to two lots. One lot was kept without feed or water for forty-eight hours, then fed and watered and kept without feed or water for another forty-eight hours. The other lot was kept on pasture. Ninety-six hours after the beginning of the test, both lots were trucked thirty-five miles to a packing plant where they were slaughtered. A total of 103 hours elapsed from the time the test was started until the lambs were slaughtered. The average weight of the fasted lambs was 73.6 pounds at the beginning of the test and 61.5 at the end, while those that were not fasted averaged 72.6 at the beginning and 73.2 at the end. The carcass weights, hot, averaged 36.0 pounds for the former and 39.2 for the latter with per cent shrink on chilling of 5.00 and 5.35 respectively. The average carcass grade was 0.17 grades poorer than low choice for the fasted lambs and 0.13 grades better than low choice for those not fasted. Average yields based on weight at beginning of test and cold carcass weight were 46.36 per cent for fasted lambs and 50.62 per cent for those not fasted. Net amount of cold meat produced was about three pounds per lamb greater for those not fasted. With spring lambs worth $13.50 per hundred pounds, fasting for four days decreased the value of these lambs in terms of meat produced by 0.87 cents per pound. Analysis of variance was used in studying the data. No significant difference in either carcass grade or carcass shrink on chilling was found. Difference in yield (4.26 per cent) between the two groups was highly significant.

Nutrition Section

C. L. Shrewsbury, *Chairman*

A STUDY OF THE EFFECT OF DIETARY FAT AND THE FAT SOLUBLE VITAMINS UPON MILK AND FAT PRODUCTION. J. K. Loosli and H. L. Lucas, *Cornell University.*

In studies previously conducted at Cornell University greater milk production has been consistently obtained with grain mixtures containing four per cent or more of ether extract than with concentrates containing less than two per cent. This difference in production might be due to factors other than the true fat content of concentrates. To obtain further information a study was made to determine whether the fat soluble vitamins have any influence upon milk and fat production when grain mixtures of different fat content are fed. Twelve Holstein cows were used to study the effect of supplements of vitamin A, vitamin D and alpha-tocopherol upon production when concentrates containing 2.2 and 5.6 per cent of ether extract were fed. Latin square design was employed. Four periods, each of five weeks duration, were used to compare the following diets: High-fat; high-fat plus vitamins; low-fat; low-fat plus vitamins. Results show a higher production of milk when the high-fat ration was fed but a smaller increase in production of fat-corrected milk. Supplement supplying 300 I.U. of vitamin A, 30 I.U. of vitamin D and 200 micrograms of alpha-tocopherol per kilo of body weight daily

had no significant effect upon milk and fat production. The supplement increased the amount of vitamin A in blood plasma and in milk fat. Blood plasma level and vitamin A in the milk continued to decline during the study. Level of dietary fat had no clear influence on carotene or vitamin A in blood plasma or milk.

THE RELATIVE EFFICIENCY FOR RUMINANTS OF THE PROTEIN FURNISHED BY COMMON PROTEIN SUPPLEMENTS. J. I. Miller and F. B. Morrison, *Cornell University.*

Alfalfa and clover hay were compared in rations in which each roughage furnished nearly the entire nitrogen and in which each was fed with corn. Timothy, alfalfa, and mixtures of timothy and alfalfa hay were compared, fed with corn and a protein supplement. No measureable differences were found in the quality of protein furnished by any of these roughages. Soybean oilmeal, linseed meal, and corn gluten meal were compared when each furnished nearly the entire nitrogen and when used as a protein supplement with corn, and either timothy hay, corn stover, or corn silage as the roughage. Each of these feeds, and also casein and dried skimmilk, furnished protein with about equal efficiency. Raw soybeans, unextracted soybean flakes, solvent-process soybean oilmeal, and "toasted" solvent-process soybean oilmeal were compared. There was little or no difference in efficiency with which digested protein was utilized, but the protein of the soybeans and soybean flakes was less digestible. Rations in which urea furnished more than one-half of total nitrogen were distinctly less efficient than similar rations containing linseed meal or mixtures of linseed meal and smaller proportions of urea. Except when urea furnished a large proportion of the nitrogen, lambs stored about 32 per cent of the digested nitrogen, biological values ranging around 62. These data from over 325 nitrogen-balance determinations show that for lambs, there is little or no difference in the quality of protein furnished by most feeding stuffs.

THE EFFECT OF DIET ON BROOD SOW PERFORMANCE. O. Burr Ross, Paul H. Phillips, and G. Bohstedt, *University of Wisconsin.*

Studies have been continued on the problem of using simplified rations for brood sows. Earlier experiments have shown that sows fed a ration of ground yellow corn 82.0%, soybean oilmeal 11.5%, ground alfalfa hay 5%, salt .5%, and limestone 1% failed to reproduce normally. Litters weaned were small in both number of pigs and size. When alfalfa was increased to 15% at the expense of corn, reproduction was normal. Brood sows on this ration weaned twice as many pigs as the sows on the 5% alfalfa ration and the pigs at weaning time were ½ heavier. Gilts from the sows fed the basal ration were continued on that ration and allowed to farrow. The deficiency or deficiencies were more acute in these second generation gilts, as indicated by abnormalities occurring in the pigs at birth. Wheat bran and middlings each fed at a level of 5%, failed to correct deficiencies of the ration. Supplementation of basal ration or bran-middlings (5% each) ration with fishmeal, tankage, brewer's yeast or molasses as late as 10 days before parturition failed to prevent the occurrence of embryological abnormalities or to stimulate lactation sufficiently to raise pigs to weaning. The deficiencies of this ration appear to be at least 2 in number. One has to do with breeding and pregnancy and the other with lactation. Preliminary experiments indicate that para-aminobenzoic acid and inositol may be the missing factors required for lactation. Parallel experiments with rats substantiate these findings. It seems probable that folic acid and biotin may also be beneficial in improving lactation in the rat fed this ration.

THE EXPERIMENTAL DESIGN NECESSARY TO OBTAIN RELATIVE NET ENERGY VALUES FROM GROUP FEEDING EXPERIMENTS HAS PROVED TO HAVE SEVERAL ADVANTAGES. Bruce R. Taylor and W. L. Blizzard, *Oklahoma Agricultural Experiment Station.*

The Oklahoma Agricultural Experiment Station has now completed five year's work in which comparable nine head lots of beef calves have been group fed to obtain data on the relative net energy values of oats, 43% cottonseed cake and ground barley when fed as partial substitutes for No. 2 shelled corn in fattening beef calves. These experiments were planned

approximately as outlined by Morrison (A.S.A.P. Proc., 1937, p. 12). The check lot which received corn and the experimental lots which received the test concentrates as partial substitutes for corn received identical amounts of all other feeds. The experimental lots were given all of the test concentrate they would consume to replace the half ration of corn they were denied; under this plan any lot of the series could be increased in grain any day of the experiment independently of the other lots. This plan disregarded early period differences in gains between lots on the assumption that all lots would even up later in the trial. The several advantages of this system where partial substitutes for corn were tested have proved to be:

1. All lots in the series consumed a maximum amount of their ration daily and hence their performance is comparable to that which feeders could expect.

2. The plan is simple enough to be popular with farmers, yet exact enough to furnish definite results.

3. Results are easily interpreted in that all lots have produced the same amount of beef.

4. The plan allows such characteristics as palatability and bulk to exert themselves in the respective rations.

Pasture and Range Section

W. P. Garrigus, *Chairman*

THE DIGESTIBLE NUTRIENTS IN BLUEGRASS MOLASSES ALFALFA-MOLASSES AND CORN SILAGES. Robert B. Hallmark and W. P. Garrigus, *University of Kentucky.*

Bluegrass-molasses silage, made from full bloom Kentucky bluegrass plus 50 pounds of blackstrap molasses per ton; alfalfa-molasses silage prepared from quarter bloom first cutting alfalfa with 60 pounds of molasses; and normal corn silage were each fed to the same three 700 pound yearling Hereford feeder steers in consecutive digestion trials consisting of a five day preliminary period and an eight day collection period. Daily dry matter intake was held at 10 pounds in all trials and no feed other than silage being tested was offered. Bluegrass-molasses silage contained, on dry matter basis, 16.6% crude protein, 5.8% ether extract, 29.3% crude fibre, 40.8% nitrogen free extract, 7.5% ash and 4927 calories of gross energy per gram. Alfalfa-molasses silage contained 17.5% crude protein, 4.3% ether extract, 27.2% crude fibre, 40.1% nitrogen free extract, 10.9% ash and 4447 calories of gross energy per gram. Corn silage analyzed 9.1% crude protein, 3.3% ether extract, 25.3% crude fibre, 57.0% nitrogen free extract, 5.3% ash and 4497 calories of gross energy per gram. Bluegrass-molasses silage contained 11.7 per cent digestible crude protein, 71.6 per cent total digestible nutrients and a nutritive ratio of 1:5.1. Alfalfa-molasses silage contained 11.7 per cent digestible crude protein, 60.8 per cent total digestible nutrients and a nutritive ratio of 1:4.2. Corn silage contained 5.6 per cent digestible crude protein, 68.4 per cent total digestible nutrients and a nutritive ratio of 1:11.2.

PASTURE ADJUSTMENTS IN THE WAR. R. H. Lush, *The National Fertilizer Association.*

According to the 1940 Census, the 31 States east of or bordering the Mississippi River and the three Pacific Coast States, which includes 57 per cent of the Nation's livestock, contain only 79,000,000 acres of plowable pasture, an increase of 27 per cent in five years, but providing only 1.86 acres per animal unit. Including woodland and other pasture gives 6.8 acres per animal unit. The nine Northeastern States have 6.3 per cent of the livestock, 41.2 per cent more plowable pasture than five years earlier, and 1.5 acres per animal unit; 14 Southern States have 17.8 per cent of the livestock, 29.2 per cent more plowable pasture than five years ago, but 2.4 acres per animal unit; and 8 Midwest States have 35.6 per cent of the livestock, 20.6 per cent increase in pasture, with 1.5 acres per animal unit. Increases in pasture have come largely through retirement of less productive acres. In war time there is added tendency to crop more productive plowable land. The most economical way of increasing livestock products for war needs is more uniform, high quality feed production from pastures and hay crops. This means intensive use of permanent and supplementary pastures with recommended ferti-

lizers, lime, and seed where necessary, manure, regulation of grazing, and more hay or silage from excess growth. Improved pasture produces cheap feed, saves on protein purchases, supplies adequate amounts of known vitamins and most minerals, aids in sanitation, reduces labor, storage, and transportation difficulties, conserves soil and farm machinery, and is available when needed most.

CHEMICAL COMPOSITION, GRAZING VALUE, AND VEGETATIVE CHANGES OF HERBAGE IN A TYPICAL PLAINS PASTURE. Warren N. McMillen, Quentin Williams, and Wright Langham, *Panhandle Agricultural Experiment Station, Goodwell, Okla.*

Beginning in May, 1939, samples of buffalo grass, blue grama and Russian-thistle were taken bi-monthly from fenced square meter plots in a 32 acre terraced pasture for chemical composition study. Density readings were taken spring and fall from unfenced plots, and yearling Herefords grazing the pasture were weighed every fifteen days during the grazing season. Moisture, crude protein, carotene and phosphorus were high in the three herbages during the early stages of growth but decreased rapidly as the plants approached maturity, usually during July. Calcium was quite variable throughout the season. Buffalo grass proved to be superior to blue grama for winter pasture, and its chemical composition is affected less by clipping. Russian-thistle proved to be higher in moisture, carotene, crude protein, ash and calcium than either buffalo or grama throughout the year. Yearling Herefords grazed the pasture for an average of 129 days for 4 seasons, made an average daily gain of .92 pound and produced a yearly average of 29.3 pounds of beef per acre. Daily gain for June was 1.47 pounds compared to .53 pound for August, indicating that gains are related to chemical composition. There was a great increase in the density of buffalo grass above the terrace ridges. In the dry season of 1940 there was a considerable decrease in density of grass on unflooded areas below terraces. Russian-thistle was prominent in dry seasons, while grasses tended to crowd it out during wet seasons of 1941 and 1942.

Sheep and Wool Section

Rufus F. Cox, *Chairman*

SOME FACTORS ENCOUNTERED IN EVALUATING FEEDS FOR FATTENING LAMBS FROM FEEDING EXPERIMENTS. H. M. Briggs, *Oklahoma Agricultural Experiment Station.*

Thirty-six lots of twenty lambs each were fed during a six-year period by a controlled gain method. An attempt was made to establish the relative net energy value of certain feeds for fattening lambs; corn and alfalfa hay were used as base feeds. In experiments covering a three-year period cottonseed meal fed in excess of the amount needed to balance the ration had an average value of 64.4 therms per hundred pounds in producing live weight gain on lambs based on an assigned value of 79.2 therms for corn. Net energy values of prairie hay varied widely but averaged 33.8 therms when fed in properly supplemented rations based on the value of 41.5 therms assigned alfalfa hay. A second series found oats to have an average value of 72.8 therms when they replaced all the corn in a ration, or 80.1 therms when one-half the corn was replaced in a lamb fattening ration. In a similar comparison barley had an average value of 70.3 therms in replacing all the corn or 64.5 therms in replacing one-half the corn. Carcasses of lambs fed corn and barley carried as much finish as corn fed lambs but barley alone did not produce comparable finish. Value for barley was slightly higher when fed in combination with corn than when fed with oats. These experiments suggest that comparable live weight gains commonly do not result in similar carcass condition of experimental lambs. The value of a feed can be expressed in terms of a standard or a base feed.

FIBER DIAMETER STUDIES OF DIFFERENT BODY AREAS. M. E. Ensminger, *Washington State College.*

The primary object of this investigation was to determine the variation in fiber diameter of samples secured from specific loci which were assumed to be representative of different body areas, namely, the head, neck, shoulder, back, side, belly, rump, upper thigh, and lower thigh.

Twenty animals consisting of Shropshires and Southdowns were used in the investigation. On the basis of this investigation, it appears possible to reduce the fiber diameter distributions to a common plan. Three groupings of the wool qualities, with rankings from finest to coarsest, can be distinguished on a fleece: (1) the head wool, (2) the dominant wool over the body generally, and (3) the rump and britch wool. The analysis of variance showed a highly significant difference between individuals in fiber diameter. With the two breeds combined, the inherent difference within itself constituted an interaction of such magnitude as to alter the individual differences regarding the fiber diameter. A significant body area-breed interaction was found in the analysis of fiber diameter. This indicates that the inherent differences between breeds are such that the different body areas in the two breeds affect fiber diameter differently. Although no sharp line of demarcation can be drawn between fiber characters over adjacent areas, there appears to be an inherent gradient in fiber diameter from the fore to the rear part of the body, and downward to the belly. Thus, the head wool is finest; whereas the wool from the lower britch is longest and coarsest.

EAR MEASUREMENTS IN RELATION TO PELT THICKNESS AND FUR CHARACTERS OF KARAKUL LAMBS. J. I. Hardy and V. L. Simmons, *United States Department of Agriculture.*

The ear skin thickness of 166 and the ear length of 158 purebred and crossbred Karakul lambs were measured to determine the relationship of ear measurements to pelt and fur characters. Ear skin thickness ranged from 0.93 to 1.87 millimeters. Lambs measuring 1.24 mm. or less in this respect are classified as thin skinned, 1.25 to 1.56 mm. moderately thick, and those 1.57 mm. or more thick skinned. Ear lengths ranged from 5.2 to 11.3 centimeters. Lambs with ears measuring 7.2 centimeters or less are classified as short-eared; 7.3 to 9.3 cm. medium; and 9.4 cm. and over, long-eared. Significant correlations were found between ear skin thickness and the thickness of the skin at the shoulder and middle back areas of the lamb's pelt ($r = 0.26$ and 0.24). Size of pelt, as represented by birth weight of the lamb, and ear skin thickness showed a highly significant relationship ($r = 0.58$). Lambs small at birth tended to have thinner ear skin than large lambs. Similarly, the pelts of small lambs were thinner than those of large ones. Small pelts tended to have a fur pattern with small curls and large pelts had large curls. Lambs having long ears generally had fur of higher desirability than those with short ears, showing a highly significant relationship in this respect ($r = 0.30$). Results indicate that ear measurements have some possibilities as an index of skin thickness and of certain fur characters that could be used in selecting breeding animals for fur production.

FINENESS OF FIBER IN EIGHT SAMPLING AREAS ON YEARLING RAMBOUILLET EWES. Elroy M. Pohle and R. G. Schott, *United States Department of Agriculture.*

The fleeces of ten yearling Rambouillet ewes were sampled from eight body areas, withers, back, rump, shoulder, side, hip, thigh, and belly. Three locks of wool from each area were taken, and each lock was cross-sectioned at three levels, base, middle, and tip. Four groups of 50 adjacent fibers were measured in each cross section, making a total of 14,400 fiber diameters for each sheep. Differences between sheep, regions, locks, cross sections, and groups were examined to determine the minimum number of locations and groups that would adequately characterize a fleece and so deacribe a working index for selection of experimental breeding stock. Groups of fibers within cross sections and locks within areas contributed least to the total variation. Areas and levels showed marked differences. A sample of 450 fiber diameters from each sheep, made up of the first group of 50 from each level in the first lock taken in three areas, shoulder, side, and thigh, was found to differentiate the sheep in approxkmately the same manner as the total of 14,400 fibers for each sheep.

CLEAN WOOL YIELD VARIATION AMONG REGIONS OF RAMBOUILLET FLEECES. Elroy M. Pohle, H. W. Wolf and Clair E. Terrill, *United States Departmeut of Agriculture.*

Clean wool yields of samples from withers, back, rump, shoulder, side, hip, thigh and belly, were compared with one another and with yield of entire fleeces to determine variability of

clean wool yield within fleeces and relative reliability of samples from various regions for predicting clean wool yield of entire fleeces. Entire fleeces and 240 small samples were obtained from 30 Rambouillet yearling ewes during May, 1939, at the Western Sheep Breeding Laboratory, Dubois, Idaho. Highest clean yields were obtained from shoulder, thigh, withers and belly with yields of 39.8, 39.7, 39.6 and 39.6 per cent of clean wool respectively. Lowest yields were obtained from rump, side and back with yields of 31.3, 31.8 and 33.5 per cent clean wool respectively. Yield of clean wool for entire fleeces was 35.4 per cent. Variation among regions and among individuals was highly significant. Variation among regions was significantly greater than that among individuals. The highest association between small samples and entire fleece was obtained from belly, thigh, side and shoulder samples as shown by correlation coefficients. Mean yield of samples from back, side and shoulder was 35.0 per cent which was very close to that of entire fleeces. Therefore results of one year's data indicate that samples taken from back and side and possibly shoulder would appear to be adequate for determining clean yield for breeding purposes where one is interested in relative values for comparing individuals or groups of individuals from the same flock.

ESTIMATION OF CLEAN FLEECE WEIGHT FROM UNSCOURED FLEECE WEIGHT AND STAPLE LENGTH. Clair E. Terrill, Elroy M. Pohle and L. Otis Emik, *United States Department of Agriculture, Dubois, Idaho.*

The present wartime shortage of scientific personnel has prompted a search for means of reducing experimental routine without sacrifice of research accomplishment. This has led to investigation of the possibility of eliminating scouring of many wool samples by estimating clean fleece weight from other fleece characters. Multiple regression equations of clean weight of wool (as determined by small samples) on unscoured fleece weight and staple length (middle of side) have been calculated on 1,037 Rambouillet, 161 Corriedale, 154 Columbia and 96 Targhee yearling ewes born during the three year period, 1938 to 1940. Multiple correlation coefficients were .78, .84, .88 and .88 for the Rambouillet, Corriedale, Columbia and Targhee respectively. Reliability of the regression equations for estimating clean fleece weights was tested by comparing clean weights calculated with the regression equation and clean weights determined from small samples with clean weights obtained from scouring entire fleeces. Such comparisons were possible on 85 Rambouillet, 55 Corriedale, 55 Columbia and 46 Targhee fleeces. The regression equation was equal to the small sample for predicting clean weight of the entire fleece for Rambouillets and Targhees but was not quite so good as the small sample for Corriedales and Columbias. Corrections for annual differences in shrinkage, based on scouring of sample lots, would be necessary to compare data from different years. Estimation of clean fleece weight from unscoured fleece weight and staple length may prove valuable for breeding purposes where individuals or groups of individuals within a breed and flock are to be compared.

A STUDY OF THE FIBER DENSITY OF THE FLEECES OF RAMBOUILLET SHEEP, H. W. Wolf, W. M. Dawson and E. M. Pohle, *United States Department of Agriculture.*

Results are presented of a study of the variation in fiber density and the accuracy of its determination within the yearling Rambouillet ewe flock at the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho. Two groups of ten sheep each were sampled in eight body positions. In group I three locks of wool were taken at each position using a Hairpin caliper. In group II the three locks were taken with a Hairpin, a Wira, and a Wyedesa caliper respectively. Significant differences existed between the density of different sheep and different body positions. The order of taking the locks within a body position was not significant, although a large variation occurred within these areas. An average density of 5255 fibers per square centimeter was found. The order of density for the different positions was top of withers—6321, just anterior to dock—6115, hip—6055, shoulder—5544, middle of back—5265, side—5237, thigh—3864, and belly—3643. Increasing the number of sheep, the number of positions, the number of locks, and the size of the skin area from which a lock was cut were all shown to increase the accuracy of determining the fiber density. From this and

other experiments, three square centimeters of skin area per lock appears to be the optimum area to sample. The Wyedesa caliper appeared to be somewhat more accurate than the Wira or Hairpin calipers. Factors affecting the accuracy as well as the ease of sampling are discussed.

Swine Section

B. W. Fairbanks, *Chairman*

THE EFFECT OF SEX ON THE DEVELOPMENT OF THE PIG. III. DIFFERENCES IN GROWTH RATE BETWEEN MALES AND FEMALES BY LINES OF BREEDING. R. E. Comstock, L. M. Winters, and J. N. Cummings, *Minnesota Agricultural Experiment Station.*

A statistical study was made of the differences in growth rate between gilts and barrows of several inbred lines of Poland Chinas and one line (known as Minn. No. 1) that was started from a cross of pigs from the Tamworth and Danish Landrace breeds. Data on a total of 2621 pigs raised in five different years were included in the study. The average daily rate of gain (weaning to 200 pounds) of barrows was .04 pound greater than that of the gilts in the case of Poland Chinas and .09 pound greater in the case of the Minn. No. 1 line. The difference between these two figures was significant. The sex difference in growth rate did not vary significantly from one line of Poland Chinas to another nor from one year to another in the case of either the Poland Chinas or the Minn. No. 1 line. The sex difference in growth rate did not change significantly with age (prior to attaining about 200 pounds weight) in the case of the Poland Chinas. In the Minn. No. 1 line the difference in growth rate between barrows and gilts showed a striking increase at about sixteen weeks of age.

THE VALUE OF LEGUME HAYS IN THE RATIONS OF FALL FARROWED PIGS. N. R. Ellis, J. H. Zeller and J. X. King, *United States Department of Agriculture.*

At the Beltsville Research Center, Beltsville, Md., a six year study was made of the value of the home-grown legume hays, alfalfa, lespedeza and soybean, to determine the extent to which these feeds can be fed most economically in the fall and winter rations to growing and fattening hogs. The hay was ground to a meal and fed at levels of 0, 5, 10, 15 and 20 per cent of the ration. The mixed rations were self-fed to hogs confined on concrete feeding pens. The rations were adjusted to a widened nutritive ratio at lot averages of 125 pounds live weight. The pigs were started on test at average weights of 50 to 63 pounds and fed to individual weights of approximately 225 pounds. A summary of results show exceptional uniformity in rate of daily gain on the different legume hays, with averages of 1.60, 1.72, 1.72, 1.66 and 1.59 pounds respectively for the lots on the 0, 5, 10, 15 and 20 per cent levels. The quantities of total feed required per 100 pounds of gain for the corresponding levels were 373, 381, 383, 406 and 425 pounds. On the average, 1 pound of ground hay had a feeding value equal to 0.58, 0.73, 0.46 and 0.40 pound of the value of a mixture of ground yellow corn, tankage and linseed meal, which it replaced at the 5, 10, 15 and 20 per cent levels, respectively. In these tests soybean hay, alfalfa hay and lespedeza hay ranked in the order given according to their replacement value.

GENETIC AND ENVIRONMENTAL CORRELATIONS BETWEEN THE GROWTH RATES OF PIGS AT DIFFERENT AGES. L. N. Hazel, Marvel L. Baker and C. F. Reinmiller, *Nebraska Agricultural Experiment Station and United States Department of Agriculture.*

The importance of heredity and environment in affecting the growth rate of pigs was studied by analysis of variance and covariance methods. Data from 994 pigs produced at the Nebraska (North Platte) Station in cooperation with the Regional Swine Breeding Laboratory were used. Correlations between the gains made in three 56-day periods from birth to 168 days, and presumably due to effects of genetic and/or environmental factors acting over relatively long periods, were .437, .161, and .547 for the first and second, first and third, and the second and third periods, respectively. The heritability of gain (fraction of the variance due to additive gene effects) was .150, .282, and .166 for the first, second and third 56-day periods, respectively. The fraction due to environmental factors common to litter mates was .474, .265 and .224,

while that due to individual environmental peculiarities was .376, .453 and .610, respectievly. Correlations between genetic effects in different periods were .708, .454 and .701 for the first and second, first and third, and the second and third periods, respectively. Correlations between the effects of litter environment were .541, .256, and .192, while those between individual environmental peculiarities were .306, .019, and .663 respectively. Gain in the second period was as accurate a measure of hereditary growth rate for the 168-day period as gain from birth to 168 days, and was only 4 per cent less accurate than values calculated by multiple regression from gains in three 56-day periods.

DISTILLERS' BY-PRODUCTS IN SWINE RATIONS. J. L. Krider, B. W. Fairbanks, and W. E. Carrolll, *Illinois Agricultural Experiment Station.*

Two experiments are reported. A basal ration of ground corn, wheat flour middlings, soybean oilmeal, tankage, fish meal, minerals and cod-liver oil has been compared with the basal plus dried distillers' solubles and with the basal plus new process corn distillers' dried grains with solubles. Pigs were on test from the creep-feeding period until they attained market weight. The data indicate (1) the basal ration was inadequate, (2) distillers' by-products contributed to the nutritive qualities of the basal ration, (3) dried distillers' solubles fed at a 6 per cent level are superior to new process corn distillers' dried grains with solubles fed at a 12 per cent level, and (4) pigs fed fortified rations up to weaning, then changed to the basal, manifest a so-called residual effect of the higher nutritional level. In the second experiment (not completed at this writing) observations are being made on (1) the effects of fortifying a lactation ration with dried distillers' solubles, (2) the results from feeding after weaning two levels of dried distillers' solubles, and (3) the differences between the basal ration plus dried distillers' solubles and the basal, plus generous amounts of alfalfa meal. Results up to weaning time do not indicate any important differences due to fortifying the lactation ration, but some so-called residual effect is being noted after weaning. Furthermore, the data at the moment indicate that the alfalfa meal addition is equal to, if not slightly superior to, an addition to the basal of 6 per cent dried distillers' solubles.

VITAMINS REQUIRED BY GROWING PIGS. V. F. McRoberts and A. G. Hogan, *University of Missouri.*

The pigs were allowed to nurse their dams for 36 to 48 hours, as in our experience they will not survive long on any ration unless they receive colostrum. They were then removed from their dams and supplied from then on with artificial milk. This contained casein 30, starch 10, sucrose 39, lard 15, salts 5, Na_2CO_3 1. These constituents are dissolved, or emulsified, in enough water to contain 20 grams of dry matter per 100 cc. The vitamin components were per 100 gms. of dry matter: Percomorph oil (vitamins A and D) 50 mg. Thiamin 0.8 mg. Riboflavin 1.6 mg. Pyridoxine 1.2 mg. Pantothenic acid 2.0 mg. Nicotinic acid 4.0 mg. Alpha tocopherol 4.0 mg. K_3, 2.0 mg. Choline 300.0 mg. Three pigs received this ration continuously for periods of 9 and 10 weeks. The pigs were normal in appearance and in rate of growth for 5 or 6 weeks. They continued to grow as long as they were under observation, but they gradually became unthrifty in appearance. This trial has been repeated twice, with a much less favorable outcome, as the pigs only survived 5 or 6 weeks. The diet was not improved by including ascorbic acid, inositol, P-aminobenzoic acid, or biotin. It is concluded that the pig requires for growth at least one unrecognized vitamin.

THE RELATION BETWEEN GROWTH RATES, WEIGHTS AND SCORES FOR PIGS AT MARKET MATURITY. Arthur E. Molln, *United States Department of Agriculture, Ames, Iowa.*

Previous studies on conformation scores of pigs at market maturity in the Regional Swine Breeding Laboratory have shown a close association between score and growth rate, as measured by weight at 180 days of age. In search of the cause for this relationship, data on 613 pigs from the 1941 spring farrowing at the Iowa station were analyzed by multiple correlation and regression methods. The mean 180-day weight was 186 pounds with a standard deviation of 31 pounds. The mean score was 40 points (a perfect score equals 54) with a standard deviation

of 3.6 points. Each pig was to be scored when its weight was near 225 pounds but for practical reasons a pen of pigs was not weighed more frequently than at intervals of two or three weeks. The mean weight at the time of scoring was 228 pounds and the average age 209 days. The scoring weight actually varied considerably, the standard deviation being 24 pounds. Scoring weight was correlated .61 with weight at 180 days and .68 with score. Score and 180-day weights were correlated .49. The multiple correlation with score as the dependent variable was .69. The standard partial regression of score on 180-day weight was .13 but was .60 on scoring weight. Apparently the faster growing pigs received higher scores mainly because they were scored when heavier and therefore carried more finish. The six items making up the total score each give a somewhat similar picture when studied separately.

STUDIES IN FEEDING SOYBEANS TO PIGS. W. J. Peterson, E. H. Hostetler, and A. O. Shaw. *North Carolina Agricultural Experiment Station.*

Forty pigs, weighing 40 lbs. each at the start of the experiment, were fed a ration consisting principally of soybeans, (78.5%) supplemented with 5% tankage, 6.5% cottonseed meal, 7.5% alfalfa, and 2.5% of a mineral mixture. All pigs were pure bred Durocs by one sire and from related dams. At the end of 8 weeks 17 pigs had made normal gains (0.83 lb. per pig daily) while the remaining pigs gained very poorly. Of the latter, seven pigs gained five pounds or less (0.06 lb. per pig daily) for the period, while one pig neither lost nor gained weight. Responses to this diet were unimproved by the addition of vitamin A in the form of cod liver oil (5,000 units per day), or when the trace elements, cobalt, manganese, iodine, and zinc were provided. Addition of 10% wheat germ was of doubtful value. A striking improvement in appetite was observed when the ration was diluted with 33% sucrose. That this beneficial effect was probably due to the widened nutritive ratio was demonstrated by the fact that similar results were obtained when corn starch (33%) was used. It is unlikely that the inhibitory effects of the basal ration are enitrely due to the high oil content inasmuch as pigs which had failed to gain on this ration responded to a standard fattening ration supplemented with 5, 10, or 15% soybean oil. Decreased appetites and gains were evident at the higher oil levels, but even here the gains were much better than those on the basal soybean ration. From the standpoint of growth and appearance, the addition of 5% oil seemed to improve the fattening ration.

THE DEVELOPMENT OF AN INBRED LINE OF SWINE FROM A CROSSBRED FOUNDATION. L. M. Winters, R. E. Comstock, and D. L. Dailey, *Minnesota Agricultural Experiment Station.*

In the fall of 1936 six Tamworth gilts secured from two different sources were bred to a Landrace boar. The following year two Tamworth gilts secured from a third source were bred to a new Landrace boar and four Landrace gilts and five of the original Tamworth females were bred to F_1 boars. The 1938 crop of pigs therefore consisted of two F_1 litters, 13 F_2 litters, four Landrace backcross litters (Landrace females), and five Tamworth backcross litters (Tamworth females). In the fall of 1938 all pure Tamworth and Landrace stock was disposed of and breeding stock was selected from the young stock on hand. The herd was closed to outside breeding. From the outset breeding stock has been selected on the basis of performance. The present herd traces almost exclusively to three of the original F_1 litters. The average F_x for the 1942 pig crop is .24. Segregation has occurred but at no time has the segregation been sufficiently wide to cause any of the pigs to be undesirable from the market standpoint. The average performance of the herd has been high throughout the six years of the project. The results indicate that a successful breed cross makes a good foundation for the development of superior lines.

NEWS AND NOTES

The annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago on December 1 and 2, 1942. Please note that this is on Tuesday and Wednesday following Thanksgiving, rather than on Friday and Saturday, as has been customary in recent years. Abstracts of papers to be presented in the various sectional meetings appear in this issue of the JOURNAL. In the general sessions emphasis will be placed on subjects directly associated with the war effort.

The Western Section held its annual meeting at the University of Wyoming on June 16 and 17, 1942. Thirty-eight members were present representing Colorado, Idaho, Montana, Nebraska, New Mexico, South Dakota and Wyoming. Twenty-four scientific papers were presented and C. A. Connaughton, director of the Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado was the featured speaker at the dinner meeting. Selection of a meeting place for 1943 was left to the officers for a later decision. Officers elected for 1943 were: President—J. H. Knox, New Mexico; Vice-President—F. S. Hultz, Wyoming; Secretary—E. B. Stanley, Arizona.

Due to cancellation of the Eastern States Exposition the North Atlantic Branch will not hold a meeting this year.

Hugh C. McPhee, Chief of the Animal Husbandry Division of the Bureau of Animal Industry, has been named Assistant Chief of the Bureau. He will continue his present duties and in addition will act as coordinator of all research work in the Bureau of Animal Industry.

Louis E. Hawkins, for the past seven years agricultural commissioner of the Kansas City Chamber of Commerce, has been appointed vice director of the Oklahoma Agricultural Experiment Station to succeed Lippert S. Ellis. Dr. Hawkins was a member of the animal husbandry staff at the Oklahoma station before going to Kansas City.

D. E. Brady of the University of Idaho has resigned to accept a position in the Animal Husbandry Department of the North Carolina State College of Agriculture.

M. G. Snell of Louisiana State University was last heard from while serving as a Major in the tank battalion in the Philippines.

D. L. Mackintosh of Kansas State College is now serving as a Captain in the Army Medical Corp, and is in the Surgeon-General's office, Washington, D. C.

R. B. Cathcart of Kansas State College is on leave for military duty.

John N. Cummings of Montana State College has accepted a position at the Middle Tennessee Experiment Station, Columbia, Tennessee.

E. A. Trowbridge of the University of Missouri returned from Argentina in September. While in Argentina he judged livestock at the Palermo show and spent some time visiting herds.

R. W. Duck, formerly state field man for the New York State Guernsey Breeders' Association has been appointed editor of *The Rural New-Yorker*.

P. R. Record has resigned from the staff of the Ohio Experiment Station at Wooster to become director of nutrition in the Field Division of the A. E. Staley Manufacturing Co., Decatur, Ill.

M. H. Kerr of Berea College has resigned to accept a position in the Animal Husbandry Department at the University of Connecticut.

Milton A. Madsen of the Utah State Agricultural College is on leave for military duty and is serving in the Sanitary Corps.

Irvin F. Edwards of Texas A and M College has been appointed assistant professor of animal husbandry at the Utah State Agricultural College. He completed the Ph.D. degree at the University of Illinois recently.

LeRoy Van Horn of Colorado State College has been appointed assistant professor of animal husbandry at the Utah State Agricultural College.

L. V. Tirrell, professor of animal husbandry, University of New Hampshire, is now on active military duty with the rank of Major in the Provost Marshal's office in Washington, D. C.

F. C. Daugherty is now head of the animal husbandry department at the University of Connecticut, Storrs, succeeding H. L. Garrigus, retired.

M. L. Buchanan resigned his position as associate professor of animal husbandry, University of Georgia, Athens, to accept a similar post at the University of Idaho, Moscow.

Fred J. Beard recently resigned his position in the animal husbandry department, Iowa State Colllege, Ames, to accept a position in the Agrcultural Marketing Administration, USDA, with headquarters in Washington, D. C.

J. B. Outhouse of the University of Maryland, was a member of an educational tour conducted by Swift & Co., in June.

L. H. Pease, assistant professor of animal husbandry, University of Tennessee, Knoxville, has resigned his position to enter the Veterinary College of the Alabama Polytechnic Institute, Auburn.

Frank G. Ashbrook and Chas. E. Kellogg of the Fish and Wildlife Service, U. S. Department of the Interior, were recently transferred to Chicago where their unit took offices in the Merchandise Mart.

C. F. Reinmiller of the Nebraska Agricultural Experiment Station has accepted a commission in the U. S. Coast Guard, and Guy N. Baker is now in charge of the animal husbandry work at North Platte.

Ben Roche has resigned his position in the animal husbandry department at the University of Wisconsin and will operate the 400-acre Merryman farm located between York, Pa. and Baltimore, Md. He will be succeeded by Malcolm Ross.

E. P. Orcutt of Montana State College and Walter Tolman of Washington State College were members of the Swift and Co. educational tour which started in Chicago on Sept. 27. 1942.

SUBJECT INDEX FOR VOLUME I

American Society Animal Production—
  1941 honor guest, 92.
  minutes of annual meeting, 90.
Animal husbandry experiments, design of, 57, 263.
Aberdeen-Angus, breeding structure, 343.

Beef—see meat.
By-products, packng house—
  competition for in new synthetic material, 74.
  economic significance, 74.
  effect on livestock prices, 73.
  history of utilization, 73.
  utilization, 72.
Breeding lambs vs. yearling ewes, 27.
Breeding program, analysis in dairy cattle, 341.
Brucellosis, genetic resistance in swine, 87, 106.

Calcium in swine rations, 71.
Carotene, intake and blood values in cattle, 68.
Cattle—
  correcting heat production for weight changes, 145.
  effect of diluters and storage on semen, 80, 149.
  effect of shark liver oil on milk production, 68.
  identical twin, 88.
  length of feeding period in performance tests, 65.
  mineral blood picture, grazing winter wheat, 14, 66.
  non-randomness of daily weights, 293.
  ovulation and estrus, 189.
  resistance of semen to unfavorable environments, 79.
  scale of heat tolerance, 85.
  staining affinity of spermatozoa, 78.
  utilizing bluestem grass in fattening, 65.
  wintering beef herd, 64.
Cattle, beef—
  Aberdeen-Angus breeding structure, 343.
  crossbreeding, 213.
  feeding period and number of animals to measure economy of gain, 285.
  fertility, 344.
  grain vs. grass in production, 83.
Cattle—Continued
  laxative nature of soybeans, 345.
  muscle-bone ratio as index, 351.
  obtaining net energy values, 353.
  phosphorus for, 345.
  producing hybrids along Gulf coast, 347
  protein supplements, 346.
  sex differences in progeny performance, 346.
Cattle, dairy—
  accuracy of live weights on pasture, 67.
  analysis of breeding program, 341.
  carotene intake and blood values, 68.
  comparison of 1st and 2nd semen collections, 80.
  dam-daughter comparisons, 349.
  effect of number of milkings on persistency, 300.
  effect of ration on semen, 79.
  equalized feeding method for lactation studies, 348.
  influencing of inbreeding, 66, 206.
  peanut meal, 67.
  predicting fat test from incomplete record, 349.
  replacement value of cottonseed meal, 348.
  value of molasses—and phosphoric acid silage, 67.
  value of short time records, 348.
Cattle, dual-purpose—
  relation of dams production to steer quality, 345.
Cellulose, seasonal changes in grass, 22.
Club work, increasing effectiveness, 48.
Cottonseed meal—
  for lambs, 277.
  for pregnant ewes, 58.
  replacement value in dairy rations, 348.

Defense, food, 77.
Design of animal husbandry experiments, 57, 263.
Distiller's by-products for swine, 359.
Dwarfism, inheritance in sheep, 87.

Eggs, incubated for swine, 38, 72.
Endocrines, relationships in reproductive failure, 3.
Environment, effect on growth of Navajo lambs, 57.

Estrus—
in cattle, 189.
in mare, 78, 309.
modification of in sheep, 343.
Experiments, design, 57.
Extension—
integrating animal husbandry in general program, 76.
livestock and family food supply program, 78.
livestock program in Colorado, 75.
measuring results, 350.
place of 4-H pig club work, 77.
producing food for defense, 77.
use of visual aid, 76.

Feeds, evaluation of on basis of digestible and metabolizable nutrients, 159.
Fertility in sheep at high altitudes, 79.
Fleece—see wool.
Fluorine in rock phosphate for sheep, 131.

Grasses, Montana, seasonal changes, 22.
Growth, lambs, effect of environment, 57.

Heat—
production, correction of for weight changes, 145.
tolerance in cattle, 85.
Hormones, sex, differences between lines of swine, 89, 111.
Horses—
development of medium weight draft, 64.
dilutors for semen, 314.
estrus and ovulation, 78, 309.
factors affecting efficiency, 350.
genetic analysis of Thoroughbred performance, 351.
present situation and future trends, 63.
seasonal influences on reproduction, 62.
twinning, 63, 155.
vitamin C and sterility, 63.
Hybrid beef cattle for Gulf coast, 347.
Hyperglycemia in lambs, 59.

Inbred line developed from crossbred swine, 360.
Inbred lines, design for testing in swine, 88, 326.
Inbreeding—
effect on differences between boars and barrows, 70.
influence on dairy cattle, 66, 206.
swine, 69.

Jack stock, seasonal influences on reproduction, 62.

Lactation—
effect of diet, 86.
effect of dietary fat and fat soluble vitamins, 352.
predicting fat test from incomplete record, 349.
studies, equalized feeding method for, 348.
Lamb—see meat.
Lambs—see sheep.
Legume hays for fall pigs, 358.
Lignin, seasonal changes in grass, 22.
Livestock—
and family food supply, 78.
extension program in Colorado, 75.

Meat—
effect of fatness on tenderness in lamb, 82.
effect of fasting on yield and grade in lambs, 352.
effect of feed and management on color in beef, 81.
effect of freezing on quality, 81.
effect of freezing on tenderness in beef, 81.
in nutrition of soldier, 85.
preparation of normal and frozen for histological study, 351.
relation of carcass quality to dam's mill production, 345.
relation of ultra-violet light and temperature to aging of beef, 351.
muscle-bone ratio as index of carcass merit, 351.
Memorials, 94.
Minerals, blood picture in cattle grazing winter wheat, 14, 66.
Mules, present situation and future trends, 36.
Mutton—see meat.

Net energy values, experimental design for obtaining, 353.
News and notes, 95, 174, 259, 361.
Nutrition, physiological approach, 179.
Nutritional—
deficiencies in concentrate mixture for swine, 85, 120.
reproductive failure, endocrine relationships, 3.

Ovulation—
in mare, 78.
relation to estrus in cattle, 189.

Pantothenic acid, minimum requirement of pigs, 85, 116.
Pasture—
adjustments in war, 354.
effect of increase on livestock production, 84.
influence of fertilizers and lime, 83.
recent agronomic developments, 82.
typical plains, chemical composition, grazing value and vegetative changes, 355.
Peanut meal for dairy cattle, 67.
Performance, analysis of in Thoroughbreds, 351.
Phenothiazine for sheep, 62, 256.
Phosphate, rock, for sheep, 59, 131.
Phosphorus—
in swine rations, 71.
for range cattle, 345.
Physiological approach to nutrition, 179.
Pigs—see swine.
Pork—see meat.
Power, farm, factors affecting, 350.
Pregnancy—
maintenance in juvenile female, 89.
multiple, fate of in sheep, 87.
President, address, 52.
Progeny testing—
effect on progress, 342.
on basis of short time dairy records, 348.
Protein—
relative efficiency of, in common feeds, for ruminants, 353.
requirements of lactating cows, 72.
supplements—
as substitutes for corn, 346.
for yearling steers, 346.
urea as substitute, 236.

Rabbits—
attempts to modify sex ratio, 343.
maintenance of pregnancy in juvenile, 89.
Range, conservation and use, 83.
Rat, effect of diet on reproduction and lactation, 86.
Rations, direct method of computing, 75, 246.
Regional swine breeding laboratory, 68.
Reproduction—
effect of diet, 86.
in sows, 353.
Reproductive failure, endocrine relationships, 3.
Ruminants, efficiency of proteins for, 353.

Selection—
for growth and productivity in swine, 342.
results of, on family basis, 342.
Semen—
bovine, effect of diluters and storage, 80, 149.
effect of ration, 79.
first and second ejaculates in bulls, 80.
metabolism and storage, 344.
smears, effect of method of making, 199.
stallion and jack dilutors, 314.
Sex—
effect on development in swine, 70, 358.
effect on growth in swine, 41.
effect on performance in cattle, 346.
ratio, attempts to modify, 343.
Sexual development in swine, 89.
Sheep—
body weight in selection, 60, 221.
breeding ewe lambs vs. yearlings, 27.
cottonseed meal for—
lambs, 277.
pregnant ewes, 58.
deficiencies of non-leguminous roughages, 86.
deficiencies of oat straw, 126.
effect of fasting on yield and carcass grade 352.
effect of wheat germ oil on reproduction, 61.
evaluating feeds for lambs, 355.
fate of multiple pregnancies, 87.
fattening lambs and gummer ewes, 61.
fertility at high altitudes, 79.
fleece—see wool.
hyperglycemia in feedlot lambs, 59.
inheritance of dwarfism, 87.
Karakul, ear measurements and fur value, 356.
modification of estrus, 343.
Navajo, effect of environment on growth, 57.
performance of ewes bred first as lambs and yearlings, 60
phenothiazine as anthelmintic, 62, 256.
rock phosphate for, 59, 131.
wool—see wool.
Silage—
digestible nutrients in various types, 354.
grass, as succulent feed, 347.
molasses- and phosphoric acid-alfalfa, 67.
Soldier, animal products in nutrition, 85.

Soybeans—
for swine, 360.
laxative effect on cattle, 345.
Spermatozoa—
resistance to unfavorable environment, 79.
staining affinity, 78.
Swine—
at market maturity, 359.
attempts to modify sex ratio, 343.
calcium and phosphorus in rations, 71.
construction of selection indexes, 69.
design for testing inbred lines, 88, 326.
developing inbred line from crossbreds, 360.
differences in growth between boars and barrows by lines of breeding, 70.
distillers by-products for, 359.
effect of diet on brood sow performance, 353.
effect of diet on reproduction and lactation, 86.
effect of nursing ability on weight of pigs, 71.
effect of sex on development, 358.
feeding soybeans, 360.
genetic and environmental correlations in growth rates at different ages, 358.
genetic resistance to brucellosis, 87, 106.
growth in boars and barrows, 41.
heritability of 180-day weight and score, 70.
incubated eggs for, 38, 72.
inheritance of conformation, 99.
lactating, protein requirements of, 72.
nutritional deficiencies of concentrate mixture, 85, 120.
pantothenic acid requirements, 85, 116.
"penny-a-pig" program, 349.
progeny testing, 342.
Regional Breeding Laboratory, development, 68.
relation between growth, weight and scores at market maturity, 359.
selection for growth and productivity, 342.
Swine—Continued
sex hormone differences between lines, 89, 111.
sexual development in large and small type, 89.
thiamin requirements as related to diet fat, 84.
trends in inbred lines, 69.
value of legume hays for fall pigs, 358.
vitamin B_6 in nutrition, 320.
vitamin requirements for pigs, 359.
Thiamin requirements of pigs, 84.
Trowbridge, E. A., 92.
Twinning in horses, 63, 155.
Twins, identical in cattle, 88.
Urea as protein substitute in ruminants, 236.
Visual aid, use of in animal husbandry, 76.
Vitamin requirements of growing pig, 359.
Vitamins, fat soluble, effect on milk production, 352.
Vitamin A in blood of cattle, effect of shark liver oil, 68.
Vitamin B_6 in nutrition of pig, 320.
Vitamin C and sterility in horses, 63.
Weights, nonrandomness of, in cattle, 293.
Wheat germ oil, effect on reproduction in sheep, 61.
Wheat, winter grazing and mineral blood picture, 14.
Wool—
clean yields in various body areas, 356.
clipper for obtaining density samples, 34.
estimating clean weight from unscoured weight and staple length, 357.
evaluation of yield in Navajo sheep, 58.
external characters of, 58.
fiber diameter in various body areas, 355.
fineness in eight sampling areas, 356.
relation between weaning and yearling, 60, 229.
study of fiber density, 357.
yield in small samples compared to whole fleece, 137.

AUTHOR INDEX FOR VOLUME I

Ahlgren, H. L., 82.
Allen, A. C., 75.
Andrews, F. N., 86, 126, 351.
Aune, B., 27, 60.

Baker, A. L., 344.
Baker, G. A., 293.
Baker, M. L., 69, 358.
Barnes, G. W., 76.
Bartlett, J. W., 66, 80, 206, 341, 349.
Bear, L. K., 76.
Bender, C. B., 347.
Benton, E. L., 76.
Berliner, V. R., 62, 314.
Black, W. H., 65, 213, 285, 345.
Blakeslee, L. H., 63, 155, 350.
Blizzard, W. L., 353.
Blunn, C. T., 57.
Bogart, R., 79, 87.
Bohstedt, G., 71, 86, 353.
Boyer, P. D., 68.
Brady, D. E., 81.
Bray, R. W., 81.
Brier, G. W., 137.
Briggs, H.M., 58, 277, 355.
Burch, J. W., 76.
Byram, H. M., 75.

Cameron, H. S., 87, 106.
Carroll, W. E., 345, 346, 359.
Casida, L. E., 87, 88, 89, 189, 343.
Chaplin, W. R., 83.
Chapman, A. B., 88.
Clark, R. T., 213, 285.
Cole, C. L., 63.
Comstock, R. E., 41, 70, 358, 360.
Cook, A. C., 345.
Cooley, R. B., 63.
Conquest, V., 72.
Cover, S., 72.
Craft, W. A., 68.
Crampton, E. W., 57, 263.
Crown, R. M., 64.
Culbertson, C. C., 61.
Cummings, J. N., 78, 309, 358.

Dailey, D. L., 89, 111, 360.
Davis, G. K., 63.
Davis, H. P., 80, 149.
Dawson, W. M., 357.
Dickerson, G. E., 88, 326, 342.
Dinsmore, W., 63.
Doyle, L. P., 59, 131.
Dyer, A. J., 87.

Easley, G. T., 79.
Eaton, O. N., 343.
Edwards, F. R., 67.
Edwards, I. F., 345.
Ellis, N. R., 84, 345, 358.
Emik, L. O., 357.
Ensminger, M. E., 58, 351, 355.

Fairbanks, B. W., 359.
Fargo, J. M., 71.
Fenn, F. U., 61.
Ferrin, E. F., 349.
Fossland, R. G., 78.
Francis, F. C., 346.
Frei, P., 81.

Gallup, W. D., 68, 348.
Garrigus, W. P., 354.
Gieseker, L., 22.
Grandstaff, J. O., 58.
Green, W. W., 89, 111.
Gregory, P. W., 57, 87, 106.
Griggs, R. F., 57.
Guilbert, H. R., 3, 293.

Hallmark, R. B., 354.
Hamilton, T. S., 236.
Hankins, O. G., 351.
Hardy, J. I., 34, 356.
Harper, C., 86, 126.
Harris, L. E., 72.
Hatfield, J. D, 59, 131.
Hazel, L. N., 69, 342, 358.
Heller, V. G., 277.
Henke, L. A., 72.
Hetzer, H. O., 71.
Hickman, C. W., 81.
Hill, G. B., 77.
Hinman, R. B., 346.
Hobbs, C. S., 346.
Hodgson, R. E., 67.
Hogan, A. G., 359.
Holbert, J. C., 343.
Hostetler, E. H., 360.
Howe, P. E., 85.
Hudson, R. S., 63, 64, 155, 350.
Hughes, E. H., 85, 87, 106, 116, 320.
Hunt, H., 63.
Hunt, R. E., 83.

Isker, R. A., 81.
Ittner, N. R., 85, 116.

Johnson, B. C., 236.
Johnson, E., 351.
Jones, J. M., 345.
Jordon, D. F., 51, 70.

Keith, T. B., 80, 120.
Kennedy, C. W., 348.
Kincaid, C. M., 352.
King, J. X., 358.
King, W. A., 67, 71.
Kirk, W. G., 64.
Kiser, O. M., 41, 70.
Knapp, B., 65, 213, 285, 345, 346, 351.
Knott, J. C., 67.
Kraybill, H. R., 90.
Krider, J. L., 38, 72, 359.
Kuhlman, A. K., 68, 348.

LaGrange, W. F., 61.
Langham, W., 14, 66, 355.
Lardy, H. A., 79, 344.
Lasley, J. F., 79.
LaVoi, D. H., 81.
Lepard, O. L., 66, 206, 341.
Loosli, J. K., 352.
Lucas, H. L., 348, 352.
Ludwin, I., 300.
Lush, J. L., 69, 99, 342, 343.
Lush, R. H., 83, 354.

Mackey, A. K., 82.
Mackintosh, D. L., 81.
Madison, L. C., 48, 77.
Madsen, L. L., 84.
Margolin, S., 341.
Maynard, L. A., 57, 179, 348.
McCampbell, C. W., 65.
McCarty, M. A., 75, 85, 120.
McCay, C. M., 38, 72.

McDonald, C. W., 84.
McIntosh, J. A., 351.
McKenzie, F. F., 79.
McMillen, W. N., 14, 66, 355.
McPhee, H. C., 343.
McRoberts, U. F., 359.
Miller, J. C., 59, 82.
Miller, J. I., 353.
Miller, R. C., 85, 120.
Mitchell, H. H., 159, 236.
Molln, A. E., 359.
Moxon, A. L., 85.
Murphee, R. L., 89.
Murphey, C. E., 82.

Nalbandov, A., 189.
Nelson, R. H., 70.
Noble, J. H., 73.

Patrias, G. C., 67.
Patton, A. R., 22.
Pearson, P. B., 59.
Peters, W. H., 52.
Peterson, W. J., 360.
Phillips, P. H., 68, 79, 86, 344, 353.
Phillips, R. W., 27, 60, 89, 213, 285, 345, 346, 351.
Pohle, E. M., 60, 137, 229, 356, 357.
Prouty, C. C., 351.

Quesenberry, J. R., 344.

Rash, J. R., 89, 111.
Reece, R. P., 66, 80, 206, 349.
Reinmiller, C. F., 69, 358.
Rhoad, A. O., 85, 347.
Robbins, E. T., 350.
Roberts, J., 351.
Robinson, W. B., 236.
Ross, O. B., 71, 86, 353.
Rupel, I. W., 68, 79.
Russell, W. C., 67.

Salisbury, G. W., 199.
Salmon, O. N., 38, 72.
Schneider, B. H., 75, 246.
Schott, R. G., 27, 60, 137, 356.
Seath, D. M., 348.
Seligman, J., 199.
Shaw, A. O., 360.
Simmons, V. L., 356.
Shrewsbury, C. L., 59, 86, 126, 131, 351.
Smith, P. C., 73.
Snapp, R. R., 345.
Sotola, J., 351.
Spangler, R. E., 80, 149.
Spencer, D. A., 27, 60, 137.
Squibb, R. L., 320.
Stangel, W. L., 75.
Steele, D. G., 351.
Stoehr, J. A., 60, 221.
Stonaker, H. H., 99, 343.
Swanson, L. E., 62, 256.
Swift, R. W., 145.

Taylor, B. R., 353.
Terrill, C. E., 60, 221, 356, 357.
Thomas, B. H., 61.
Thorne, G. B., 74.
Thorp, W. T. S., 85, 120.
Trowbridge, E. A., 64.

Underbjerg, G. K. L., 78, 80, 149.

Vail, G. E., 81.

Wanderstock, J. J., 346.
Warner, K. F., 78.
Warwick, E. J., 87, 89, 343.
Watson, J. C., 61.
Weatherby, E. J., 87, 89.
Weber, A. D., 65.
Whatley, J. E., 70.
Whitehurst, V. E., 62, 256.
Willett, E. L., 199.
Williams, D. W., 66.
Williams, Q., 355.
Willman, J. P., 38, 72.
Winters, L. M., 41, 70, 111, 358, 360.
Wolf, H. W., 356, 357.
Work, S. H., 72.

Young, H. H., 74.

Zelle, M. R., 86, 126.
Zeller, J. H., 89, 358.

XU

XU